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Hydraulic Research in the United States 1965



United States Department of Commerce

National Bureau of Standards

Miscellaneous Publication 270

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*Located at Boulder, Colorado 80301.

**Located at 5285 Port Royal Road, Springfield, Virginia 22171.

UNITED STATES DEPARTMENT OF COMMERCE • John T. Connor, *Secretary*

NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Director*

Hydraulic Research in the United States 1965

(Including Contributions from Canadian Laboratories)

Edited by Helen K. Middleton



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FOREWORD

The information contained in this publication was compiled from reports by the various hydraulic and hydrologic laboratories in the United States and Canada. The cooperation of these agencies is greatly appreciated. The National Bureau of Standards cannot assume responsibility for the completeness of this publication. We must depend upon reporting laboratories for the completeness of the coverage of their own programs, as well as upon new laboratories engaged in hydraulics to bring their activities to our attention.

Projects are numbered and the number once assigned is repeated for identification purposes until a project is completed. The numbers 5258 and above refer to projects reported for the first time. All projects are in active state, unless otherwise noted under (f).

The National Bureau of Standards does not maintain a file of reports or detailed information regarding the research projects reported by other organizations. Such information may be obtained from the correspondent listed under (c) or immediately following the title of the organization reporting the work. It is of course understood that any laboratory submitting reports on its work will be willing to supply information to properly qualified inquirers.

A similar bulletin, "Hydraulic Research," compiled and published by the International Association for Hydraulic Research, contains information on hydraulic research being conducted in foreign countries. This bulletin is edited by Professor H. J. Schoemaker, Director of the Hydraulic Laboratory at the Technical University of Delft, Netherlands, and Secretary of the International Association for Hydraulic Research. Copies may be obtained from the Secretary at \$7.50 each (postage included).

A. V. Astin, Director

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Key to Projects

(a) Number and title of project	(e) Description
(b) Project conducted for	(f) Present status
(c) Correspondent	(g) Results
(d) Nature of project	(h) Publications

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HYDRAULIC RESEARCH IN THE UNITED STATES

UNIVERSITY OF ARIZONA.

(4620) EFFECT OF CROP COVER ON EFFICIENCY OF SPRINKLER IRRIGATION UNDER VARYING CLIMATIC AND OPERATING CONDITIONS.

- (b) Agricultural Experiment Station.
- (c) Mr. Kenneth R. Frost, Department of Agricultural Engineering, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Laboratory for theory and design.
- (e) Precise water balance of growing crops under sprinkler application of irrigation water. Crops are grown in a tank of soil 12 feet in diameter and 2 feet deep. Instrumentation permits measurement of loss or gain of 0.005 inches of water on the area of the tank. Measurements permit evaluation of loss or gain of water from dew, rain, irrigation, evaporation, and transpiration on crops at any stage of growth and as functions of ambient atmospheric conditions.
- (g) Evapotranspiration during sprinkling is approximately equal to that during non-sprinkling periods since evaporation from wet foliage replaces normal transpiration. Daily evapotranspiration ranges from 6-8 times the one-hour evapotranspiration at the period of peak rates. Cloud cover reduces evapotranspiration by one-third from that at full-run under the same vapor pressure deficit.
- (h) "Factors Affecting Evapotranspiration Losses During Sprinkling," by K. R. Frost. Transactions of the American Society of Agricultural Engineers, Vol. 6, No. 4, pp. 282-283 and 287, 1963.

(4621) SPRINKLER IRRIGATION OF CITRUS UNDER SOUTHWESTERN CONDITIONS.

- (b) Agricultural Experiment Station.
- (c) Mr. Kenneth R. Frost, Department of Agricultural Engineering, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Field investigation for design data.
- (e) Investigation of the use of sprinkler application of irrigation water in production of Arizona crops. Irrigation efficiencies under sprinkling as compared to efficiencies under surface applications. Irrigation scheduling and system design for sprinkler application of water. Crop yields per unit of land and per unit of water as functions of method of water application, soil type, irrigation schedules, and crop species and variety.
- (g) Field tests of sprinkler irrigation on citrus. On coarse textured soils water savings of 50% have been achieved by sprinkling.
- (h) "Sprinklers versus Flood Irrigation of Citrus," by K. R. Frost. American Society of Agricultural Engineers, Paper No. 64-204, 1964.

(4622) GROUND WATER SUPPLIES.

- (b) Agricultural Experiment Station, The Univ. of Arizona; City of Tucson; and the Pima County.
- (c) Prof. Harold C. Schwalen, Department of Agricultural Engineering, Univ. of Arizona, Tucson, Arizona 85721.
- (e) Detailed continuing groundwater inventory of selected basins in Arizona including at present the Santa Cruz from Nogales to Red Rock, Avra, Altar, Little Chino, Reddington Area of the San Pedro. Groundwater contour maps are prepared annually. Specific yields storage coefficients and transmissibilities are determined from well tests. An electric analog of the Tucson groundwater basin is being developed.
- (g) Groundwater elevation data has been developed for all areas studied. Volumetric unwatering estimates have been prepared. Water balance estimates have been prepared

for the Tucson Metropolitan, Sahuarita Districts, and Cortaro Districts. Open files are maintained from which current ground water level data is available for any location in the area studied.

- (h) Irrigated Areas of Arizona, State Map. Arizona Agricultural Experiment Station and Agricultural Extension Service Folder No. 100, 1963. Irrigated Areas of Arizona, Sectional Map, ibid. Folder No. 101, 1963.

(4624) HYDROLOGIC CHARACTERISTICS OF A GROUNDWATER BASIN.

- (b) City of Tucson and Pima County through a cooperative agreement with the Agricultural Engineering Department, Arizona Agricultural Experiment Station.
- (c) Mr. John Ferris, Department of Geology, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Analytical, laboratory, and field investigations for development, operation, design and theory, for Doctoral dissertation.
- (e) Attempts are being made to determine the hydrologic characteristics - specific yield and/or storage coefficient and transmissibility -- of the groundwater basin in the Santa Cruz Valley near Tucson, Arizona. Well tests are being made at sites where observation wells are available. Water budget analyses are being used in connection with mathematical models. A passive element electric analog model is being developed.
- (g) Well tests made during the past two years indicate that realistic values of specific yield and/or storage coefficient are not obtained from such tests in the Santa Cruz Valley. Values of transmissibility are more consistent and reasonable.

(4625) CRITICAL TRACTIVE FORCE OF UNIFORM SANDS.

- (b) Departmental in cooperation with the U. S. Geological Survey.
- (c) Dr. Emmett M. Laursen; Department of Civil Engineering, Univ. of Ariz., Tucson, Arizona 85721.
- (d) Analytical and laboratory investigation related to theory.
- (e) Analytic and experimental attempts to relate the average boundary shear to the incipient movement of sediment particles composing the boundary.
- (g) The experimental data plot on a Shield's diagram as two parallel lines for the laminar and turbulent cases. Both cases extend over the range usually considered the transition between a laminar sub-layer and fully rough turbulent flow. An approximate analysis lends credibility to the experimental results.
- (h) "A Continuation of the Study of Critical Tractive Force", by Robert B. Conklin, Thesis for Master of Science in the Dept. of Civil Engineering, The Univ. of Arizona, May 1964.

(4626) SCOUR AT RELIEF BRIDGES.

- (b) Departmental in cooperation with the U. S. Geological Survey.
- (c) Dr. Emmett M. Laursen; Department of Civil Engineering, Univ. of Ariz., Tucson, Ariz. 85721.
- (d) Laboratory investigation related to theory and design.
- (e) To find the effect of sediment size and velocity of flow on the limiting depths of clear-water scour in simple relief-bridge geometries. First, the case of the long contraction will be studied, then the case of the long gradually-contracting channel. The last case to be studied will involve various simple abrupt contractions. Throughout the experiments, examination of the assumptions of the analysis of Dr. E. M. Laursen will be made and also of the time

- dependency of depth of scour insofar as feasible.
- (g) Equipment has been constructed and the experimental program has been started.
- (4627) A STUDY OF PARTIALLY SATURATED FLOW IN SAND-EPOXY RESIN COLUMNS.
- (b) Departmental.
- (c) Professor Richard L. Sloane; Department of Civil Engineering, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Laboratory investigation related to theory.
- (e) The flow of water through soils often takes place under conditions of partially saturated flow. The prediction of fluid distribution and pressure under conditions of partially saturated flow is important to those interested in the problem of recharge to the ground water table from water applied to the surface of the earth. This study of partially saturated flow will make use of vertical columns made of sand grains cemented together with epoxy resin. The use of this type of sand columns will result in a model for which properties such as void ratio and particle arrangement will remain constant during a series of tests.
- (4628) RADIOCARBON AS A TRACER IN WATER SUPPLY PROBLEMS.
- (b) Research Corporation unrestricted venture grant and Geochronology Dept. funds.
- (c) Dr. Paul E. Damon, project leader; Geochronology Laboratories, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Laboratory and field research; doctoral thesis.
- (e) The study of ground water movement through aquifers has been limited by the slow rate of movement of the subsurface waters. Thus, if a tracer is introduced, only limited information is obtainable between the times of spiking and observation. However, radiocarbon (C^{14}) has been naturally introduced into ground water reservoirs continuously throughout geologic time and, consequently, movement which has taken place during the last 45,000 years may be studied. In addition nuclear technology is now producing radiocarbon at a greater rate than nature and so this artificially produced radiocarbon may also be used to trace recent water movements. Furthermore, it represents a potential hazard to health and therefore it is essential to monitor the increment for the safety of the community. We propose to monitor the present carbon-14 content of surface water and organic matter in the Southwest and to measure the radiocarbon content of subsurface waters. The source of the carbon in water will be determined by C^{12}/C^{13} measurements. This data will be related to ground water hydrologic problems such as the rate of laminar flow through aquifers, their permeability, the source and rate of recharge, paleoclimatology, radioactive contamination in water supplies, and the waste disposal problem.
- (g) Incomplete.
- (4630) DEVELOPMENT OF HYDRAULIC MODELS ANALOGOUS TO SUBSURFACE GEOLOGIC CONDITIONS FOR STUDYING AND DEMONSTRATING THE CHARACTERISTICS OF GROUND WATER MOVEMENT.
- (b) National Science Foundation.
- (c) Dr. John W. Harshbarger, Dept. of Geology, University of Arizona, Tucson, Ariz. 85721.
- (d) Laboratory investigation, design, development and operation.
- (e) The purpose of the project is to clarify the characteristics of laminar flow in groundwater movement in a manner which will enable a visual flow net analysis. Hydraulic models are being developed which consist of consolidated media simulating sedimentary rock, enclosed in a water-tight case with a transparent side. Basic geologic structures and lithologies can be synthesized and colored inks can be inserted into the flow system of the model, forming visible flow lines. These flow lines can then be observed and analyzed in order to better understand the pattern of laminar groundwater flow as controlled by geologic factors. A few of the empirical model experiments which are being carried out include: 1) Refraction of flow bands across lithologic interfaces. 2) Continuity of flow around and through highly permeable and impermeable lenses of different lithologies. 3) Flow net systems caused by a single pumping well. 4) Flow-net system of mutual interference of depression cones caused by pumping multiple wells. 5) Artesian aquifer systems. 6) Infiltration phenomenon. Models are being developed for use in education in science and hydrology at the college and university level.
- (f) Completed.
- (g) Models consisting of plexiglass cases containing artificially consolidated porous media which can be arranged in a nearly infinite variety of geologic structures and hydrologic situations have been developed. A wide variety of these models have been constructed and through their use it has become possible for the college student to obtain a clear description and understanding of previously conceived groundwater theories.
- (4631) GROUND WATER HYDROLOGY OF THE WESTERN DESERT, U.A.R.
- (b) In cooperation with General Desert Development Authority, Cairo, U.A.R.
- (c) Moh. H. I. Salem, Univ. of Ariz., Tucson, Ariz. 85721.
- (d) Analytical study of field data; operation and development; for doctoral dissertation.
- (e) An electric analog model of the subsurface geologic and hydrologic conditions of the western desert of the U.A.R., Lybia, Sudan and Tehad is being constructed. Presently the area of recharge is in the high regions of Tehad and of Darfur in the Sudan. Ground water is discharged into the Nile and into the Qattera Depression. The distribution of the fundamental differential equations in the system will be determined taking into consideration the boundary conditions. It is hoped that the equations can be solved with the use of the electric analog model. The effects on the Ground Water system due to changed boundary conditions such as the completion of the Aswan High Dam (The Nile is expected to recharge water to the aquifer after the dam is completed) or the initiation of the Qattera depression project, will be included in the general analysis of the western desert.
- (4632) ENERGY BALANCE OF DESERT REGIONS.
- (b) Departmental project.
- (c) Dr. William D. Sellers, Inst. of Atmospheric Physics, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Field investigation for testing of new equipment.
- (e) Project is to accurately measure all components of the energy balance over various types of desert surfaces. Emphasis is placed on measuring the heat used for evaporation.
- (g) Evaporation rates measured in the dry stream channel of Walnut Gulch in S.E. Arizona over an 18-day period in October 1961 were high enough to indicate that natural recharge of the water table is negligible when the watertable is 48 to 90 cm below the surface. For dry soils evaporation rates appear to decrease with increasing wind speed; the reverse is true for wet soils. Practically all the radiative energy incident on short grass is used for evaporation.

(4633) PHYSICS OF CONVECTIVE CLOUDS AND CLOUD MODIFICATION.

- (b) National Science Foundation. Also, some assistance by U. S. Weather Bureau and U. S. Forest Service.
- (c) Dr. Louis J. Battan, Institute of Atmospheric Physics, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Field investigations of the physics of convective clouds and the effects of cloud seeding with silver iodide.
- (e) The program involves detailed observations of convective clouds during the summer by means of radar, a pair of high resolution cameras. A network of recording rain gages is employed to measure rainfall. Cloud seeding is conducted with airborne silver-iodide generators. A carefully controlled randomization scheme is employed to decide on which days to seed. The results are analyzed statistically. In addition a physical evaluation is made to uncover information about the fundamental nature of cloud and precipitation formation.
- (g) To date the experiments have failed to show that cloud seeding with silver iodide can increase rainfall from the convective clouds commonly observed in the summer in the vicinity of Tucson. The analyses suggest that the quantity of rainfall does not depend on the ice nuclei properties of the air. This result leads to the inference that seeding with ice nuclei (such as silver iodide particles) is not likely to be successful in increasing rainfall from convective clouds.
- (h) "Some Observations of Vertical Velocities and Precipitation Sizes in a Thunderstorm", by Louis J. Battan, *Journal of Applied Meteorology*, Vol. 3, Aug. 1964, Pp. 415-420. "Relationship Between Cloud Base and Initial Radar Echo", L. J. Battan, *Journal Applied Meteorology*, 2, June 1963, pp. 333-336. "Some Doppler Radar Observations of a Decaying Thunderstorm", L. J. Battan, J. B. Theiss and A. R. Kassander. *Proceedings of the 1964 World Conference on Radio Meteorology*, Sept. 1964. American Meteorological Society.

(4634) REDUCTION OF EVAPORATION LOSSES BY USING MONOMOLECULAR FILMS.

- (b) U. S. Bureau of Reclamation, Procter and Gamble Co. and Institute.
- (c) C. Brent Cluff, Institute of Water Utilization, Univ. of Ariz., Tucson, Arizona 85721.
- (d) Laboratory and field; operation, development and theory.
- (e) For the U. S. Bureau of Reclamation the project has the following objectives:
 - (1) To determine at one or more field sites the advisability of using the long-chain alcohols n-eicosanol and n-docosanol for the suppression of evaporation from small reservoirs in arid regions.
 - (2) To determine the optimum concentrations of long-chain normal alcohols and emulsifiers in emulsions, the optimum concentration of long-chain normal alcohols in solutions and the relative merits of each.
 - (3) To determine the optimum spacing of dispensing tubes and rate of dispensing of emulsions and solutions through gravity flow and pressure-type dispensers as functions of wind velocities and reservoir area for reservoirs up to ten acres in size.
 - (4) To determine the suitability of commercial humidity transducers as means of estimating evaporation savings at small reservoirs. For the Procter and Gamble Co. tests are being conducted in an effort to obtain a commercially acceptable scheme for reduction of evaporation on stock ponds and small reservoirs using tallow and longer chain alcohols.
- (g) Results to date indicate that the most promising method of maximizing evaporation

savings on small reservoirs is the wind-activated dispensing of n-eicosanol and n-docosanol in the form of an emulsion. Savings of 22 per cent over a one-month period were attained on a small test pond using this method in the summer with savings increasing to 40 per cent in the winter. Savings up to 10 per cent in the summer and 20 per cent in the winter were attained during the same period simply by treating, once a day, an identical pond with powdered material.

(4635) INVESTIGATION OF SITES, METHODS, ACQUIFER DETERIORATION CONTROL, AND EFFECTS OF ARTIFICIAL GROUND WATER RECHARGE OF ALLUVIAL BASINS TYPICAL OF THE ARID SOUTHWEST UNITED STATES.

- (b) Institute.
 - (c) Dr. L. G. Wilson, Institute of Water Utilization, University of Arizona, Tucson, Arizona 85721.
 - (d) Laboratory and field; operation and development.
 - (e)
 - (1) To evaluate various methods of artificial ground water recharge under arid land conditions.
 - (2) To evaluate in laboratory and field various types of flocculants and grassland filters for removal of suspended and colloidal material from recharge water and for relative costs.
 - (3) To determine the effect on the aquifer and ground water of recharging sediment laden flood water.
 - (4) To evaluate the status of ground water recharge practices in a water conservation and disposal program using saline industrial effluent.
 - (5) To evaluate the effect of quality of industrial effluent on the quality of native groundwater subsequent to recharge.
 - (6) To evaluate the efficiency of grassland filters for post treatment of reclaimed sewage effluent in a program to conserve and expand the uses of such effluent.
 - (7) To evaluate the moderating influence on the neutron scattering method of soil moisture evaluation of various packing materials around access tubing during installation in coarse geologic material.
 - (8) To evaluate the effects produced by organic matter additions to surface soil on soil properties influencing recharge rates; and to determine the nature of the by products of microbial metabolism producing such effects.
 - (g) Experiments were conducted to determine the factors involved in the utilization of grass filters for sediment reduction in flood water. All tests were conducted using coastal and common bermuda grasses. It was found that flow rate, infiltration rate, length of grass plots, initial turbidity, and height and stage of development of grass were all interrelated factors in removal of sediment.
- (4637) EFFECT OF FIRE AND RESIDUAL ASH ON VEGETATION-SOIL-WATER RELATIONS IN SELECTED PONDEROSA PINE STANDS.
- (b) Dept. of Watershed Management in cooperation with U. S. Bureau of Indian Affairs, White Mt. Apache Tribe.
 - (c) Dr. A. L. McComb, Prof. A. R. Croft, and Mr. Malcolm J. Zwolinski, Dept. of Watershed Management, Univ. of Arizona, Tucson, Ariz. 85721.
 - (d) Analytical, laboratory and field investigation; basic and applied. For doctoral dissertation.
 - (e) The study will include a series of laboratory and field experiments to evaluate the influences of wild fire and controlled burning on the chemical and physical properties of a forest soil as these may affect the basic processes of surface and soil water movements.

- Laboratory studies will be carried on to determine changes in the structure, pore space, and chemical characteristics of the soil due to burning of the ground cover. Field studies employing North Fork type infiltrometers, soil and soil moisture sampling will be carried on to supplement and extend the results of the laboratory studies.
- (g) Preliminary studies and literature review indicate conflicting and inconclusive evidence of the effects of fire and ash residue on water-soil relations. Early results of infiltration runs show that decreased water intake due to burning could be short-lived.
- (5152) DISPOSITION OF SUMMER RAINFALL IN PONDEROSA PINE STANDS AS INFLUENCED BY VEGETATION DENSITY AND RELATED PHYSIOGRAPHIC FACTORS.
- (b) Departmental in cooperation with U. S. Bureau of Indian Affairs, White Mt. Apache Tribe.
- (c) Dr. A. L. McComb, Prof. A. R. Croft, and Mr. Howard G. Halverson, Dept. of Watershed Management, Univ. of Arizona, Tucson, Ariz. 85721.
- (d) Analytical, field and laboratory investigations; basic and applied. For doctoral dissertation.
- (e) Study aimed at evaluating effects of density of vegetation stocking on the disposition of summer rainfall in Ponderosa pine stands, and at developing methods of predicting effects of regulated stocking (stand management) on water yield. Three 0.6 plots are used in the study; one with the dense 40-45 year old pine stand undisturbed; one with a similar pine stand with 80% of basal area thinned; and one with the deep rooted woody and forb vegetation completely removed. Measurements include complete soil-vegetation inventories, and those of climate, soil moisture, evapotranspiration, vegetation and allied factors needed in evaluating effects of the treatments studied in the processes influencing soil-water relations, tree growth and water yield.
- (g) Analyses being undertaken.
- (5153) ANALYSIS OF IRRIGATION PUMPING EFFICIENCIES AND COSTS.
- (b) Agricultural Experiment Station, Univ. of Arizona and Bureau of Reclamation, Phoenix Development Office, Region 3.
- (c) Dr. C. D. Busch, Dept. of Agricultural Engineering, Univ. of Arizona, Tucson, Ariz. 85721.
- (d) Field investigation for the design, operation and development.
- (e) Fifty-four wells located in Central Arizona were measured for lift, discharge, and power input. Fixed and variable costs were also collected. This data is being used to determine the costs and efficiencies of pumping irrigation water so that current practice may be assessed and future practices estimated.
- (g) Deep-well pumping plant costs and efficiency in Pinal and Maricopa Counties of Arizona.
- (5154) EVALUATION OF SUB-SURFACE IRRIGATION WITH PLASTIC PIPE.
- (b) Agricultural Experiment Station.
- (c) Dr. C. D. Busch, Dept. of Agricultural Engineering, University of Arizona, Tucson, Arizona 85721.
- (d) Theoretical and field investigations.
- (e) Investigation of the nature of moisture movement and crop response to irrigation supplied by buried perforated plastic pipe. Plots with sub-surface irrigation and sprinkler irrigation have been instrumented for metered water delivery and irrigation by soil moisture stress. Bermuda grass is the indicator crop. The experiment compares the two irrigation systems on a basis of water use. Model work is planned to describe moisture movement.
- (g) Subsurface application of irrigation water to turf has resulted in the same water use and turf condition as sprinkler application.
- (5155) STORM FLOW IN A STREET NETWORK.
- (b) Departmental
- (c) Dr. Emmett M. Laursen, Dept. of Civil Engineering, The Univ. of Arizona, Tucson, Arizona 85721.
- (d) Analytical investigation for design.
- (e) Development of a simple methodology to compute approximate backwater curves for storm flows in a street network.
- (5156) ELECTRIC ANALOG OF THE GROUND WATER SYSTEM IN CHAJ DOAH, PAKISTAN.
- (b) Departmental in cooperation with the water and soils investigation division of West Pakistan.
- (c) Maqsood Ali Shah Gilani, c/o U.S.G.S./G.W., P. O. Box 4070, Tucson, Arizona, U.S.A.
- (d) Laboratory investigations correlated to field studies; for Master's Thesis.
- (e) Since the start of canal investigation in West Pakistan, the ground water levels have been rising. This has produced water-logging and excessive soil salinity in much of the arid and semi-arid areas. Millions of acres of land have thus been forced out of cultivation. To reclaim the affected land and to check the further deterioration of irrigated lands, investigations were started by government of West Pakistan. Field data obtained in one of the affected areas, known as Chaj Doah, comprising of about 5,000 square miles is being used to construct an electric analog model for the purpose of studying the cause and effect relationships.
- (f) Completed.
- (5157) THE IDEAL FLOW FIELD IN A SMALL WATERSHED AND ITS RELATION TO THE DRAINAGE NETWORK.
- (b) Departmental.
- (c) Mr. John J. Hickey, Box 9, Dept. of Geology, University of Arizona, Tucson, Ariz. 85721.
- (d) Experimental, for Master's thesis.
- (e) Assuming that the surface of a basin at any particular time may be described by, $\nabla\phi = 0$, it is proposed to determine if the areal position of tributaries in a small "homogeneous" watershed can be shown to be a function of the flow field in the watershed at any particular time in its history.
- (f) Completed.
- (5158) A TRANSPARENT MATRIX SYSTEM FOR THREE DIMENSIONAL HYDRAULIC FLOW MODELS.
- (b) National Science Foundation.
- (c) Dr. Jerome J. Wright, Dept. of Geology, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Laboratory investigation, design, development and operation.
- (e) The purpose of this project is to develop a transparent porous media system capable of demonstrating the laminar flow of ground water movement. When a colorless porous media is saturated by a colorless liquid with the same index of refraction, in a closed system of optimum size, a high degree of transparency will be attained. In order to produce flow in the system a hydraulic gradient will be imposed upon it. Colored dyes will be introduced so that the fluid movement may be visually observed. Experimentation with various immersion liquids, porous media, light source and dyes will be a necessary part of the project. Once developed, this system could be used in the construction of hydraulic flow models where the characteristics of three dimensional laminar flow analogous to ground-water movement, may be studied.
- (5159) EFFECTS OF PHREATOPHYTE REMOVAL ON STREAM-FLOW AND TOTAL WATER YIELD.

- (b) Departmental and U. S. Bureau of Reclamation, with cooperative assistance of the U. S. Bureau of Indian Affairs, San Carlos Apache Tribe; U. S. Geology Survey; and U. S. Forest Service.
- (c) Dr. A. L. McComb, Prof. A. R. Croft, Mr. Arnett C. Mace, Jr. and John M. Tromble, Dept. of Watershed Management, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Analytical, field and laboratory investigations; basic and applied.
- (e) Study designed to evaluate effects of phreatophytes, phreatophyte removal and replacement vegetation in relation to physiographic factors on consumptive use of capillary and ground water. Two study sites are located along the Gila River near Coolidge Dam on the San Carlos Indian Reservation. One site, Salt Creek, a tributary to the Gila River, is typical of many of the phreatophyte zones found along the smaller and intermittent streams of the state. The second site on the Gila River is located 5 miles downstream from Salt Creek and is typical of the phreatophyte zones found along the major streams in the southwest. Three channel cross sections 700 to 900 feet long and 600 feet wide have been selected on Salt Creek and will be used for specific studies of the influence of phreatophytes and revegetation on consumptive use of water. Two sections extending from free water to a bench along the canyon bottom of the Gila River have been selected for study similar to Salt Creek. Replacement vegetation, mainly grasses, will be evaluated by analysis of emergence, survival, establishment, percentage ground cover, forage production, and reinfestation of phreatophytes. Each species will be replicated three times. Evapotranspiration of phreatophytes, and replacement vegetation will be determined by the aerial tent method. Instrumentation effects of this method will be evaluated by studying enclosure effects on the plant and comparing the energy budget inside and outside of the tent. Soil moisture will be determined by the neutron scattering technique and water table fluctuation by ground water wells in all areas. Detailed soil, vegetation, and climatic variables are being measured to aid in interpretation of the effect of phreatophyte and replacement vegetation on consumptive use of water in relation to physiographic factors.
- (5348) OPEN CHANNEL TRANSITIONS.
- (b) Departmental.
- (c) Dr. Thomas Carmody, Dept. of Civil Engrg., Univ. of Arizona, Tucson, Ariz. 85721.
- (d) Laboratory investigation for development.
- (e) Both contractions and expansions in canal sections will be studied looking toward improvements in design methods.
- (5349) EFFECT OF SILT LADEN WATER ON INFILTRATION IN ALLUVIAL CHANNELS.
- (b) Departmental.
- (c) Dr. Emmett M. Laursen, Dept. of Civil Engrg., Univ. of Arizona, Tucson, Ariz. 85721.
- (d) Laboratory and field investigation.
- (e) In arid regions a large part of the natural recharge is through the bed of intermittent streams. A better understanding of the effect of silt content is needed to predict natural recharge and to evaluate works to promote recharge.
- (5350) FLOW CHARACTERISTICS IN A TWO-DIMENSIONAL EXPANSION.
- (b) Departmental.
- (c) Dr. Thomas Carmody, Dept. of Civil Engrg., Univ. of Arizona, Tucson, Ariz. 85721.
- (d) Laboratory investigation.
- (e) The first of a series of general studies of separated flow in finite boundaries.
- (5351) HYDRAULICS OF SURFACE IRRIGATION.
- (b) Agricultural Experiment Station.
- (c) Dr. C. D. Busch, Dept. of Agricultural Engineering, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Field evaluation of application of theory applied research.
- (e) Part of a regional research activity. Flow theories developed in laboratories elsewhere in the region will be field tested.
- (5352) SPRINKLER IRRIGATION OF COTTON WITH HIGH SALT CONTENT WATER.
- (b) Agricultural Experiment Station.
- (c) Dr. C. D. Busch, Dept. of Agricultural Engineering, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Experimental investigation, applied research.
- (e) Crop response and salt balance in soil when cotton is sprinkled with water in the range of 4.2 to 4.6 millimohs/cm.
- (5353) SEEPAGE REDUCTION INVESTIGATIONS.
- (b) Procter and Gamble Co. and the Institute of Water Utilization.
- (c) Mr. C. Brent Cluff, Institute of Water Utilization, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Field; operation and development.
- (e) To field test various seepage control agents in specially designed double wall seepage pits to determine their relative effectiveness in the prevention of seepage.
- (g) Results to date indicate that the materials tested are less effective in the prevention of seepage in field installations than in the laboratory. Additional tests are being made to determine the cause for this difference.
- (5354) PREDICTION OF WATER MOVEMENT IN UNSATURATED SOILS.
- (b) Agricultural Experiment Station.
- (c) Dr. D. D. Evans, Dept. of Agricultural Chemistry and Soils, Univ. of Arizona, Tucson, Arizona 85721.
- (d) The project is theoretical and experimental and would be classified as basic.
- (e) To develop and validate theory for the simultaneous flow of energy and water in soils, particularly to regions of evaporation of water.
- (5355) DEEP-WELL WATER VELOCITY LOGGER.
- (b) Departmental and U. S. Public Health Service.
- (c) Dr. J. W. Harshbarger, Dept. of Geology, Univ. of Arizona, Tucson, Arizona. 85721.
- (d) Laboratory and developmental.
- (e) The purpose of the project is to attempt to adapt the electromagnetic flow meters developed for the medical field to the measurement of low rates of vertical flow in well bores in order to obtain data which can be interpreted in terms of the composition of the aquifer and its contributions to the well flow from each strata.
- (5356) TEMPERATURE EFFECTS ON FLOW INDUCED MOVEMENT OF HEXADECANOL IN UNSATURATED SOIL.
- (b) Departmental.
- (c) Dr. D. D. Evans, Dept. of Agricultural Chemistry and Soils, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Laboratory research.
- (e) An apparatus has been developed to permit the study of the effect of temperature upon the flow induced movement of hexadecanol in unsaturated sandy soil. An attempt will be made to follow the day-to-day movement of the C₁₄-tagged hexadecanol through the soil by means of autoradiographs. Measurements

- of flow volume versus time will also be made.
- (f) Temporarily suspended.
- (5357) GROUNDWATER MOVEMENT IN THE TUCSON BASIN AS RELATED TO THE STRUCTURE AND STRATIGRAPHY.
- (b) Departmental.
- (c) Dr. J. W. Harshbarger, Dept. of Geology, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Field investigation, using surface and subsurface information. Applied research for master's thesis.
- (e) Groundwater movement in the Tucson Basin is controlled by the stratigraphic variants and the structural elements within the basin. A detailed study of these variants (using subsurface well information) and elements (using surface, subsurface and geophysical information) can provide an approach to the understanding and prediction of water movement as man's withdrawal of groundwater combines with these geological controls. The projected magnitudes and rates of de-watering in the basin are being studied to determine the anticipated lateral and vertical movement of the groundwater.

- (5358) AN APPROACH TO STREAM GAUGING BY USE OF CONTINUOUS INJECTION OF TRACER ELEMENTS.
- (b) Departmental.
- (c) Dr. Eugene Simpson, Hydrology Dept., College of Mines, Univ. of Arizona, Tucson, Arizona 85721.
- (d) Field investigation, to fulfill requirements for Master of Science Degree.
- (e) Instantaneous injection of tracer elements for stream gauging has been established and is a well proven process. The thesis will evaluate the feasibility of a continuous injection of tracer elements as a means of stream gauging. Value of such a study lies in the future automation of the procedure as a means of gauging intermittent stream flow in the southwest. The first test of gauging stream flow by continuous injection of tracer elements will be conducted under optimum control conditions in which steady flow exists and the volume of flow will be determined by Price current meter measurements and/or a weir. Further testing of the method will be conducted under natural field conditions of the Gila River utilizing gauging stations of the U. S. Geological Survey, Gila River Phreatophyte Project. If possible a final test will be run on a tributary under flash flood conditions.
- (h) Bureau of Reclamation, 1961, Report on field demonstration--use of isotopes in hydrographic measurements, Gila Project - Arizona: Bur. Reclamation, open-file report (mimeographed) in collaboration with: Lynch Radiation Services and University of California, P. 1-36.

UNIVERSITY OF ARKANSAS, Agricultural Experiment Station.

- (2255) GROUND WATER, RESOURCES AND RECHARGE, IN THE RICE GROWING AREA OF ARKANSAS.
- (b) Arkansas Agricultural Experiment Station cooperative with U. S. Geological Survey and U. S. Corps of Engineers.
- (c) Prof. Kyle Engler, Head of Agricultural Engineering Dept., University of Arkansas, Fayetteville, Arkansas.
- (d) Basic and applied research.
- (e) The straight 26-inch sand-packed recharge well has been tested for one year and results have not proved completely satisfactory. Main difficulties encountered arise in duplicating test condition under field situations. The sand packed well seemed to filter out plugging material but redevelopment proved more difficult than in

the gravel packed well. Separan AP-30 was tried but proved unsatisfactory for conditions as encountered in this test. A slow gravel filter has been constructed and will be tested as a means of clarifying recharge water during the winter and spring of 1960-61.

- (f) Discontinued.
- (h) U. S. Geological Survey Water Supply Papers available from the Office of the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402: "Artificial Recharge of Ground Water--Grand Prairie Region, Arkansas," Kyle Engler, F. H. Bayley 3rd, and R. T. Sniegocki, 1615-A, 1963, 32 pp. "Hydrogeology of a Part of the Grand Prairie Region, Arkansas", R. T. Sniegocki 1615-B, 1964, 71 pp.

UNIVERSITY OF ARKANSAS, Civil Engineering Dept.

- (4068) TURBULENT FLOW IN POROUS MEDIA.
- (b) U. S. Public Health Service, Div. of Water Supply and Pollution Control.
- (c) Prof. John C. Ward, Assistant Professor of Civil Engineering, University of Arkansas, Fayetteville, Arkansas 72701.
- (d) The project is experimental and theoretical and is classified as basic research with definite practical applications.
- (e) The purpose for which the work is being done is to describe the effects of stratification on the permeability of an unconsolidated porous medium in quantitative terms.
- (g) In this work it was demonstrated that the size distribution of commercially available ion exchange resins, sands, gravels, anthracite coal, and granular activated carbon appear to be well represented by a geometrically normal frequency distribution. This distribution is completely definable in terms of the geometric mean and the geometric standard deviation, both of which can be calculated from the results of a conventional sieve analysis. In addition an equation was developed that relates the permeability of an unconsolidated porous medium to the geometric mean and geometric standard deviation of its size distribution by weight. The equation appears to give reasonably accurate values of the permeability for all the previously mentioned porous media and glass beads.
- (h) "Turbulent Flow in Porous Media," by J. C. Ward, Journal of the Hydraulics Division, ASCE, Vol. 90, No. HY 5, Proc. Paper 4019, Pages 1-12, Sept., 1964.

BOLT BERANEK AND NEWMAN INC.

- (5190) SOUND RADIATED FROM A TURBULENT BOUNDARY LAYER.
- (b) Bureau of Ships Fundamental Hydromechanics Research Program Administered by the David Taylor Model Basin.
- (c) Dr. J. E. Ffowcs Williams, Bolt Beranek and Newman Inc., 50 Moulton St., Cambridge, Mass. 02138.
- (d) Basic theoretical research.
- (e) The research is aimed at clarifying the exact role of a solid surface in determining the mechanism by which sound generated in a turbulent boundary layer is radiated. It is known that if the surface is very large, it merely acts like a passive reflector, and if it is small, it constitutes an additional dipole field. The intermediate size situation remains obscure and it is on this problem that the work is concentrated.
- (g) The role of a responsive homogeneous surface of infinite extent has been studied. The main result of the analysis is that no fundamentally more efficient source of

sound is introduced by the surface motion. The radiation remains quadrupole in character. The surface merely accounts for a reflection of the turbulence generated sound, with the reflection coefficient being identical to that for plane acoustic waves.

- (h) Quarterly Progress Reports. Obtainable from David Taylor Model Basin.
- (5191) INTERACTION OF DISTRIBUTED SURFACE VIBRATIONS WITH AN ADJACENT BOUNDARY LAYER FLOW.
 - (b) Bureau of Ships Fundamental Hydromechanics Research Program Administered by the David Taylor Model Basin.
 - (c) Dr. Francis J. Jackson, Bolt Beranek and Newman Inc., 50 Moulton St., Cambridge, Mass. 02138.
 - (d) Basic theoretical and experimental.
 - (e) The program is aimed at studying the stability of a flow in contact with a non-rigid (responsive) wall. The effect of the wall response on the properties of the adjacent boundary layer flow are of special interest. Particular attention is being paid to the effects of actuating the wall motion by external means.
 - (g) An analysis of the Reynolds stress very close to the wall indicates that the direction of energy flux between the mean flow and the boundary layer disturbances (which may give rise to instability) depends upon the properties of the wall, and its response to the pressure fluctuations produced by the disturbance field.
 - (h) Quarterly Progress Reports. EBN Technical Report No. 1138, "Reynolds Stress Near a Flexible Surface Responding to Unsteady Air Flow," 3 June 1964. Obtainable from David Taylor Model Basin.

POLYTECHNIC INSTITUTE OF BROOKLYN.

- (5359) SCOUR TESTS OF NEW JERSEY DAM NUMBER 3.
 - (b) Hackensack Water Co.
 - (c) Dr. Chilton A. Wright, Polytechnic Inst. of Brooklyn, 333 Jay St., Brooklyn, New York 11201.
 - (d) Performance of a given design of the dam.
 - (e) The dam is about 15 ft. high and will be built on a sand foundation. There is a movable gate on the crest. The model is made to a scale of 1 to 35 and set in a wooden flume 20 inches wide with a sand bed downstream. The purpose is to study performance of the model and to scour under various flows.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Division of Engineering and Applied Science.

- (1548) PROBLEMS IN HYDRODYNAMICS.
 - (b) Office of Naval Research, Dept. of the Navy.
 - (c) Prof. Milton S. Plesset, Calif. Inst. of Tech., Pasadena, California.
 - (d) Theoretical and experimental; basic research.
 - (e) Studies of cavitating and noncavitating flow; dynamic behavior of cavitation bubbles; theoretical studies of cavitation damage.
 - (h) "A General Analysis of the Stability of Superposed Fluids," by M. S. Plesset and Din-Yu Hsieh, Physics of Fluids, Vol. 7, No. 8, Aug. 1964, pp. 1099 - 1108. "Radiation Due to the Radial Motion of a Conducting Sphere in a Magnetic Field," by Giulio Venezian, Div. of Eng. and Applied Science, Calif. Inst. of Tech. Report No. 85-24, March 1963. "Temperature Effects in Cavitation Damage," by Robert E. Devine and Milton S. Plesset, Div. of Eng. and Applied Science, Calif. Inst. of Tech. Report No. 85-27, April 1964. "Effects of Thermal Conduction in Sonoluminescence," by Robert Hickling, Jour. of the

Acous. Soc. of Amer. Vol. 35, No. 7, pp. 967 - 974, July 1963. "Bubble Dynamics" Cavitation in Real Fluids, by M. S. Plesset, Elsevier Publishing Co., Amsterdam (1964). "Collapse and Rebound of a Spherical Bubble in Water," by Robert Hickling and M. S. Plesset, Physics of Fluids, Vol. 7, No. 1, Jan. 1964, pp. 7 - 14. "Stability of Helium II Flow Down an Inclined Plane," Din-Yu Hsieh, Physics of Fluids (in press). "Stability of a Conducting Fluid Flowing Down an Inclined Plane in a Magnetic Field," Din-Yu Hsieh, Calif. Inst. of Tech. Div. of Eng. and Applied Science (in press).

CALIFORNIA INSTITUTE OF TECHNOLOGY, W. M. Keck Laboratory of Hydraulics and Water Resources.

- (3670) TURBULENCE AND PARTICLE ENTRAINMENT IN SETTLING TANKS.
 - (b) U. S. Public Health Service.
 - (c) Prof. Vito A. Vanoni, Calif. Inst. of Tech., Pasadena, California 91109.
 - (d) Experimental research.
 - (e) Flow in a settling tank is simulated by introducing water with a low turbulence level and uniform velocity into a flume 15 feet long with the bed covered by a thin layer of sediment. As the flow proceeds into the flume, a boundary layer develops and becomes progressively thicker. The entrainment of particles is observed visually and the corresponding shear stress is deduced from measured velocity profiles. Completed.
 - (f) Data on critical shear stress for entraining fine sand particles of diameters of 0.1 mm and smaller have been observed.
 - (g) "Measurements of Critical Shear Stress for Entraining Fine Sediments in a Boundary Layer", by Vito A. Vanoni, W. M. Keck Lab. of Hyd. and Water Resources, Calif. Inst. of Tech. Report No. KH-R-7, May 1964.
- (3671) EVALUATION OF FORMULAS FOR THE TRANSPORT RATE OF SEDIMENT BY ALLUVIAL STREAMS.
 - (b) Laboratory project.
 - (c) Prof. Vito A. Vanoni, Calif. Inst. of Tech., Pasadena, Calif. 91109.
 - (d) Analytical research using published data.
 - (e) The sediment discharge calculated by several well-known formulas is compared with actual measured sediment discharges in natural streams. The results are presented as graphs of sediment discharge against water discharge.
 - (f) Project is continuing.
- (4075) MECHANICS OF FLOW IN SAND-BED CHANNELS AT VERY LOW RATES OF SEDIMENT TRANSPORT.
 - (b) National Science Foundation.
 - (c) Prof. V. A. Vanoni or N. H. Brooks, Calif. Inst. of Tech., Pasadena, California 91109.
 - (d) Experimental and theoretical research.
 - (e) Studies are made (1) of the development of dunes with time on a sand bed with flows which produce low rates of sediment transport and of the resulting changes in flow resistance as the dunes grow and (2) on the mechanism of entrainment of sediment by flowing water and (3) of relations of geometric parameters of dunes and the frictional resistance to flow produced by the dunes with a view to predicting resistance from dune dimensions.
 - (f) Project is continuing.
- (4076) PRECISION TILTING FLUME.
 - (b) National Science Foundation.
 - (c) Prof. Vito A. Vanoni and Prof. Norman H. Brooks, Calif. Inst. of Tech., Pasadena, California 91109.

- (d) Development of facilities.
 (e) The flume which is 40 meters long, 110 centimeters wide, and 50 centimeters deep is mounted on a rigid supporting structure carried on jacks. Water is circulated by pumps with variable speed drives for controlling the flow rate. The slope of the flume can be adjusted continuously without interrupting an experiment, up to a maximum of 2 per cent. The flume system can produce programmed unsteady flow and will be equipped with convenient recording equipment for observing such flows. It is designed as a general purpose facility for studies of open channel flow problems such as sediment transportation, boundary layers, and wave propagation in shear flow.
 (f) Completed.
 (g) Flume has been completed and is being used in several research projects.
- (4561) DYNAMICS OF DENSITY-STRATIFIED RESERVOIRS.
 (b) U. S. Public Health Service (research grant).
 (c) Prof. Norman H. Brooks, Calif. Inst. of Tech., Pasadena, Calif. 91109.
 (d) Basic theoretical and experimental research.
 (e) (1) In reservoirs having density variation with depth, the pattern of flow toward an outlet may be quite different from the flow in a homogeneous reservoir. The withdrawal pattern has been studied experimentally in a laboratory tank of water having a linear density profile induced either by dissolved salt or heat. Application will ultimately be in management of water quality in rivers by selective withdrawal from reservoirs.
 (2) A theoretical stability analysis has also been made for viscous uniform two-layer flow down an inclined plane, a problem related to density underflows in reservoirs.
 (g) (1) At very low Reynolds numbers there is a distinct "withdrawal layer" extending upstream at the level of the outlet. Fluid above and below this layer is not withdrawn through the outlet. Results of two-dimensional experiments agree with a theoretical analysis based on the laminar boundary layer equations and the diffusion equation for the substance causing density variation. A theoretical analysis has also been made of axisymmetric flow to a point sink.
 (2) Report (see below) includes curves of critical Reynolds number as function of depth ratio and density ratio, and also curves for relative amplitude of surface and interfacial waves.
 (h) "Viscous Stratified Flow Towards a Line Sink," R. C. Y. Koh, W. M. Keck Lab. Report No. KH-R-6, Calif. Inst. of Tech., Jan. 1964.
 "Stability of Two-Layer Stratified Flow Down an Inclined Plane," T. W. Kao, W. M. Keck Lab. Report No. KH-R-8, Calif. Inst. of Tech., August 1964.
 "A Free-Streamline Solution of Stratified Flow into a Line Sink", by T. W. Kao, Journal of Fluid Mechanics (in press).
 "Viscous Stratified Flow Towards a Sink", R. C. Y. Koh, manuscript submitted for publication (Journal of Fluid Mechanics), Nov. 1964.
 "Hidden Flow Patterns in Reservoirs," Norman H. Brooks Engineering and Science Magazine (Calif. Inst. of Tech.), April, 1964, pp 12-13.
- (5013) DYNAMICS OF DENSITY-STRATIFIED GROUND-WATER FLOW.
 (b) U. S. Public Health Service (research grant).
 (c) Prof. Norman H. Brooks, Calif. Inst. of Tech., Pasadena, Calif. 91109.
 (d) Basic theoretical and experimental research.
 (e) Slight density variations often affect ground-water flow patterns. Water which is recharged artificially may not mix readily with native waters but develops density stratification in the aquifer. Studies include problems such as overturning of unstably layered systems, flow due to sources of buoyancy and effects of density difference on fluid dispersion in flow through porous media.
- (5014) WAVE INDUCED OSCILLATIONS OF SMALL MOORED VESSELS.
 (b) Dept. of the Army, Corps of Engineers.
 (c) Prof. Fredric Raichlen and Prof. Vito A. Vanoni, Calif. Inst. of Tech., Pasadena, Calif. 91109.
 (d) Experimental and theoretical research.
 (e) Serious ship and dock damage can be caused by wave induced oscillations of moored vessels. The ship and its mooring system constitute a dynamic system capable of resonant oscillations. The objective of this research is to investigate the motion of small boats moored to fixed or floating platforms in a standing wave environment. The study is directed toward an understanding of the problems of mooring small craft in marinas and to providing information that will assist in planning and operation of marinas.
 (g) A wave basin with wave generator and measuring and recording equipment have been assembled and the research is proceeding actively.
- (5360) MECHANICS OF SLUG FLOW IN STEEP CHANNELS.
 (b) Los Angeles County Flood Control District.
 (c) Prof. Vito A. Vanoni and Mr. Richard Brock, Calif. Inst. of Tech., Pasadena, Calif. 91109.
 (d) Experimental and theoretical research.
 (e) Detailed laboratory observations are being made of slug flows (also called roll waves) with a view to checking the many theoretical studies of this problem and to evaluating problems arising from slug flows in the many high-velocity flood channels in Los Angeles County.
- (5361) EXPERIMENTS ON TURBIDITY CURRENTS.
 (b) Petroleum Research Fund.
 (c) Dr. Gerard V. Middleton, McMaster Univ., Research Fellow in Geology, 1964-1965, Calif. Inst. of Tech.
 (d) Experimental research.
 (e) Comparative studies will be made on the behavior of density underflows composed of salt solutions, clay suspensions, and coarse sediment suspensions. Particular attention will be devoted to the movement of the head of the current, and to deposition of sediment from the current.
 (f) Preliminary experiments have been completed and an apparatus is under construction.
 (g) A report on the preliminary experiments is available on request.
 (h) "Density Currents Experiments" (abstract). Program, Soc. Econ. Paleontologists and Mineralogists, New Orleans, April 1965.
- (5362) ANALYSIS OF STEADY FIELD DRAINAGE THROUGH A SYSTEM OF UNDERGROUND PIPES.
 (b) Laboratory project.
 (c) Mr. E. John List, Calif. Inst. of Tech., Pasadena, Calif. 91109.
 (d) Theoretical and numerical analysis.
 (e) A common procedure for drainage of agricultural lands is installation of parallel underground drain tiles. Design parameters include flow, permeability, and drain spacing, depth, and diameter. List's theoretical solution includes all of these parameters for the first time (Journal Geoph. Res., 69 (1964), 16, 3371-3382).
 (f) Completed.
 (g) Because of the complexity of the theoretical solution, it was not directly useful. Therefore, with aid of a high-speed computer, graphical solutions were prepared to show the relationship of all design parameters for an optimum drainage system.

- (h) "Steady Flow to Tile Drains Above an Impervious Layer--A Theoretical Study" by E. John List, W. M. Keck Lab. Report No. KH-R-9, Calif. Inst. of Tech., 1964.

UNIVERSITY OF CALIFORNIA, College of Agriculture,
Department of Irrigation.

- (23) HYDROLOGY OF IRRIGATION SUPPLIES IN CALIFORNIA.
- (b) University of California.
 - (c) Prof. R. H. Burgy and Mr. D. C. Lewis, Dept. of Irrigation, Univ. of Calif., Davis, California.
 - (d) Experimental and field investigation; applied research.
 - (e) Hydrologic investigations of mountain watersheds are being conducted on pilot watersheds in three areas of the state. Measurements are being made of rainfall, surface runoff, erosion, and groundwater storage and outflow. The hydrologic effect of vegetative conversions on the watersheds is under long-range study. Radioactive tracers are used to study groundwater movement and depth of rooting of trees. A neutron moisture meter is used to measure moisture content in the soil and rock above the water table. Micro-meteorological techniques and equipment are being tested to provide an independent evaluation of evapotranspiration from the study watersheds.
 - (h) "Water Use by Native Vegetation and Hydrologic Studies", by D. C. Lewis and R. H. Burgy, Annual Report No. 5, 1963-64, Dept. of Irrigation, Univ. of Calif., Davis, Calif.
- (1816) DRAINAGE IN RELATION TO IRRIGATION.
- (b) University of California.
 - (c) Dr. J. N. Luthin and Mr. R. V. Worstell, University of California, Davis, California.
 - (d) Basic and applied research.
 - (e) The drainage of sloping land has been studied. An equation has been developed in cooperation with Dr. P. Schmid of the Swiss Forest Research Station for the shape of the water table that is in equilibrium with the rainfall. A paper has been published in the Journal of Geophysical Research. Computer programs have been written in cooperation with Dr. George Taylor of the Ohio State University on the shape of the water table in equilibrium with rainfall on sloping land. The computer solutions take into account the flow in the capillary fringe. The seepage surface emerges as part of the solution.
 - (h) "The Drainage of Sloping Lands", by Paul Schmid and J. N. Luthin, Jour. Geophys. Res. 69:1525-1529, 1964.
- (4086) MISCIBLE AND IMMISCIBLE FLUID DISPLACEMENTS IN RELATION TO SOLUTE MOVEMENT IN SOIL AND OTHER POROUS MATERIAL.
- (b) University of California
 - (c) Drs. J. W. Biggar and D. R. Nielsen, Dept. of Irrigation University of California, Davis, California.
 - (d) Theoretical and experimental; basic and applied.
 - (e) The simultaneous transport of fluids and solutes through porous media is under investigation. The mixing and spreading of the fluids in the medium, the interaction of the fluids with each other and the medium have been studied. The work will help define the nature of the porous structure of materials, and the coupling between velocity and diffusion in the dispersion process. Leaching phenomena, disposal of industrial and radioactive wastes, and the movement of pesticides in soil water depend upon the dispersion process.
 - (g) Mathematical models of dispersion previously reported have been compared with experimental
- data obtained from studies on soil, glass beads, sandstone and sand columns. More recently the effects of the density and viscosity of the fluids on the mixing has been studied using Cl^{36} and glass bead medium. Leaching phenomenon, disposal of industrial and radioactive wastes and the movement of pesticides in soil water involve dispersion processes.
- (h) " Cl^{36} Diffusion During Stable and Unstable Flow Through Glass Beads," J. W. Biggar and D. R. Nielsen. Soil Sci. Soc. Amer. Proc., Sept.-Oct. 1964.
- "Soil Profile Studies Aid Water Management for Salinity Control," D. R. Nielsen, J. W. Biggar and R. J. Miller. California Agric. 18, 1964.
- (4088) IRRROTATIONAL FLOW OVER A VERTICAL, SHARP-CRESTED WEIR.
- (b) University of California.
 - (c) Dr. Theodor S. Strelkoff, Dept. of Irrigation, University of California, Davis, Calif.
 - (d) Theoretical, basic research.
 - (e) A digital computer is used to carry out the approximate numerical solution of an exact integral equation, derived by conformal mapping and singularity distribution, and describing the two-dimensional flow over weirs ranging in height from zero to infinity. Project being extended to other geometries and to flows with given degree of rotationality.
 - (h) "Solution of Highly Curvilinear Gravity Flows," by Theodor S. Strelkoff. Proc. Paper 3950, Jour. of Engin. Mechanics Div., Proc. Amer. Soc. Civil Engineers, No. EM3, June 1964.
- (4857) USE OF WELLS IN AREA DEVELOPMENT.
- (b) University of California.
 - (c) Dr. V. H. Scott, Department of Irrigation, University of California, Davis, California.
 - (d) Theoretical and field research including doctoral thesis research.
 - (e) Three studies are in progress: (1) Consideration of the influence of a decreasing discharge rate in solution for unsteady flow to wells; (2) the influence of mutual interference of multiple well systems; and (3) the use of down wells in multiple aquifers as a means of controlling the water table and disposing of poor quality water.
 - (g) A general analytical solution has been developed for unsteady flow of groundwater to a well having a decreasing discharge rate. A graphical solution has been proposed to determine the aquifer characteristics from pumping test data. The graphical solution requires the numerical computation and tabulation of a mathematical function called the "variable well function". Values of this function have been determined.
 - (h) "Tables of the Function $f(A,B) = \frac{1}{B} \exp(Ay - \frac{B}{y}) \frac{dy}{y}$ " revised, by G. Aron, M. A. Abu-Zied, and V. H. Scott. WS & E Series No. 2001, 17 pp., July 1964.
- (5142) VARIABLE FLOW UNDER A VERTICAL GATE.
- (b) University of California.
 - (c) Dr. Theodor S. Strelkoff, Dept. of Irrigation, Univ. of Calif., Davis, California.
 - (d) Experimental, theoretical; basic research, for Ph. D. dissertation.
 - (e) Time-dependent flows under sluice gate moving vertically in its own plane are being studied in a laboratory flume. A numerical, quasi-steady, potential-flow analysis is being developed to complement the experimental investigation.
- (5143) PROFILE OF A WETTING FRONT ADVANCING IN AN IRRIGATION BORDER.
- (b) University of California.
 - (c) Dr. Theodor S. Strelkoff, Dept. of Irrigation, Univ. of Calif., Davis, Calif.

- (d) Experimental, theoretical; applied research for M. S. and M. E. theses.
- (e) This is a special case of surge on a dry bed. Vegetation is simulated in a laboratory flume by an array of uniformly distributed vertical rods set into the bottom. Flow is introduced at the head end, and the passage of the wave through the rods is measured by electrical depth gauges. A theoretical expression describing an established such flow is being tested. Area of interest is being extended to include zone of establishment and influence of infiltration.
- (h) "Profile of a Shallow Water Front Advancing Through Artificial Vegetation," by Wessel P. Wessels. M. S. Thesis, Univ. of Calif., 1964.
- (5144) UNSTEADY FLOW IN OPEN CHANNELS.
- (b) University of California.
- (c) Dr. Theodor S. Strelkoff, Dept. of Irrigation, Univ. of Calif., Davis, Calif.
- (d) Theoretical; basic research.
- (e) A computer-implemented numerical solution is being developed for the one-dimensional continuity, momentum, and energy equations of unsteady flow in canals of arbitrary cross-sectional form. A method is sought which will permit automatic tracking of spontaneously formed shock-discontinuities in the profile. Under investigation is a method of "smearing" the shocks by introducing into every positive wave of the continuous solution an energy loss equivalent to that occurring in a discontinuity of comparable geometry.
- (g) An effective computer program has been developed for gradually variable flow with surface profile discontinuities only at checks, siphons and pumping plants. Arbitrary initial and boundary conditions of depth, velocity and discharge are easily introduced.
- (5145) NONLINEAR ANALYSIS OF HYDROLOGIC SYSTEMS.
- (b) University of California.
- (c) Dr. J. Amorocho, Dept. of Irrigation, Univ. of Calif., Davis, California.
- (d) Theoretical and experimental investigation; basic and applied research.
- (e) (1) Studies on the mathematical theory of nonlinear systems with lumped and with distributed parameters. (2) Characterization of time- and space-variable rainfall distributions. (3) Development of methods for the establishment of nonlinear inflow-outflow relationships for natural catchments. (4) Laboratory and field application of (5) above.
- (g) Experiments completed to date on laboratory catchments under simulated rain reveal large departures from the conditions of linearity and invariance implicit in the "unit hydrograph" concept, and suggest that similar behavior can be expected in natural watersheds. A new approach in the analysis suggested and approximate procedures applicable to floods due to uniformly distributed storms have been developed. Further development of mathematical theory of nonlinear systems is under way. Statistical procedures for the mathematical characterization of storms from data on California watersheds are being tested.
- (h) "A Critique of Current Methods in Hydrologic Systems Investigation." J. Amorocho and W. E. Hart. Trans. Amer. Geophys. Union 45(2):307-321, 1964.
- "Use of Laboratory Catchments in the Study of Hydrologic Systems". J. Amorocho and W. E. Hart. ASCE Jour. Hydr. Div., in press.
- (5146) THE EFFICIENCY OF ENERGY DISSIPATORS.
- (b) University of California.
- (c) Dr. J. Amorocho, Dept. of Irrigation, Univ. of Calif., Davis, Calif.
- (d) Theoretical and experimental investigation; applied research.
- (e) Development of analytical criteria for the efficiency of energy dissipating structures in terms of the characteristics of the flow stream delivered and the shear stresses over the boundary of the receiving channels. Experimental evaluation of efficiencies from hydraulic model data.
- (g) "Energy efficiency" and "shear efficiency" criteria have been developed as means of evaluating: (1) The effectiveness of a structure in dissipating energy; and (2) the scouring potential of the outflowing water. Experiments with a vortex-type energy dissipator illustrate the application of these criteria for designs based on hydraulic model investigations.
- (5462) FLOW CONVEYANCE EFFICIENCY OF TRANSITIONS AND CHECK STRUCTURES IN A TRAPEZOIDAL CHANNEL.
- (b) Dept. of Water Resources, State of Calif.
- (c) Dr. J. Amorocho, A. F. Babb, Dept. of Irrigation, Univ. of Calif., Davis, Calif.
- (d) Experimental; applied research.
- (e) Investigation of the flow conveyance efficiency of transitions and check structures in the California Aqueduct. A detailed study of energy conversion effects is being performed on a 1:16 scale model of structures including warped and cylinder quadrant inlet transition, elevated rectangular gate sections with piers, and warped outlet transitions.
- (g) The results obtained so far indicate that losses are substantially smaller than those computed by conventional design techniques. Analysis and theoretical work is proceeding.
- (h) "Flow Conveyance Efficiency of Transitions and Check Structures in a Trapezoidal Channel" (California Aqueduct), Progress Report No. 1, Water Science and Engineering Papers No. 1004, Department of Irrigation, Univ. of California, Davis, August 1964.
- (5463) SACRAMENTO-SAN JOAQUIN DELTA FISH COLLECTION FACILITIES.
- (b) Dept. of Water Resources, State of Calif.
- (c) Dr. J. Amorocho, A. F. Babb, Dept. of Irrigation, Univ. of Calif., Davis, Calif.
- (d) Model studies.
- (e) (1) Investigation of velocity approach patterns to the Primary Fish Collection Facilities which will be constructed upstream of the inlet to the Delta Pumping Plant. The structure consists of a large rectangular channel subdivided by vertical walls into smaller channels, each containing a system of louvers which will deflect the fish into bypass pipes leading to a secondary louver system. The uniformity of the approach velocity patterns is being studied as a function of the relative positions of the louvers, the trashracks, and the noses of the vertical partition walls. (2) Investigation of the expanding closed conduit transitions leading to the secondary louver system for evidence of separation and subsequent return flow.
- (5464) HYDRAULIC MODEL PERFORMANCE OF THE NORTH SAN JOAQUIN TERMINAL STRUCTURE.
- (b) Dept. of Water Resources, State of Calif.
- (c) Dr. J. Amorocho, A. F. Babb, Dept. of Irrigation, Univ. of Calif., Davis, Calif.
- (d) Hydraulic model investigation for design development.
- (e) Investigation of the performance of "The North San Joaquin Terminal Structure", a gated control located at the terminus of the North San Joaquin Division of the California Aqueduct, as an energy dissipating device for certain conditions of differential head across the gates.
- (f) Completed.
- (g) The structure operates satisfactorily under conditions of equal gate openings. Unequal

gate openings lead to highly asymmetrical flow patterns downstream of the structure and subsequent high velocities.

- (h) "Hydraulic Model Performance of the North San Joaquin Terminal Structure", Progress Report No. 1, Water Science and Engineering Papers No. 1003, Department of Irrigation, Univ. of California, Davis, August 1964.

(5465) HYDRAULIC PERFORMANCE OF THE THERMALITO POWER PLANT.

- (b) Department of Water Resources, State of Calif.
- (c) Dr. J. Amorocho, A. F. Babb, Dept. of Irrigation, Univ. of Calif., Davis, Calif.
- (d) Model studies for design development.
- (e) Studies on the approach conditions to the penstocks and bypass spillway are being made, including the effects of the structural shape and bed geometry upon the formation of vortices at the inlets to these structures. Investigations of the flow configurations in the tailwater area will be made, particularly in the vicinity of the draft tubes and the bypass stilling basin.

(5466) DEL VALLE DAM AND SPILLWAY.

- (b) Department of Water Resources, State of Calif.
- (c) Dr. J. Amorocho, A. F. Babb, Dept. of Irrigation, Univ. of Calif., Davis, Calif.
- (d) Model studies for design development.
- (e) The study of a non-gated ogee-crested chute spillway including the effect of upstream geometry upon the flow configurations with the chute. Shock wave patterns in the spillway were studied in some detail. This configuration includes an auxiliary flood control outlet tunnel discharging through a large opening in the spillway floor which was tested for various combinations of flood control and spillway discharges.
- (g) Shock wave patterns occurring in the open chute were compared with predicted patterns computed on the basis of conventional theory, and analysis is proceeding on the effects of velocity non-uniformity on the wave forms. The effect of bottom boundary geometry is also being studied.
- (h) "Investigations on the Regimen of Flow of Spillway Chutes" (Del Valle Dam), by J. Amorocho and A. F. Babb. Progress Report No. 1, Water Science and Engineering Papers No. 1005, Dept. of Irrigation, Univ. of Calif., Davis, August 1964.

UNIVERSITY OF CALIFORNIA, Dept. of Civil Engineering, Fluid Mechanics Laboratory.

(1554) SEA WATER CONVERSION RESEARCH.

- (b) State of California.
- (c) Prof. Everett D. Howe, Coordinator, Saline Water Conversion Research, University of Calif., 1301 South 46th Street, Richmond, California.
- (e) The purpose of this project is to discover whether there is available any method for the large-scale, low-cost demineralization of sea water. The project includes a number of investigations, of which the following have been active during 1963-64: (1) Multiple effect rotating evaporator; (2) evaporation by immiscible fluid heat transfer; (3) vacuum flash distillation (low temperature difference method); (4) solar distillation; (5) electrodialysis tests; (6) freeze-separation; (7) ion exchange; (8) biological studies; (9) capillary control of vapor transfer gaps; (10) reverse osmosis pilot plant; (11) thermodynamic and economic analysis; (12) experimental heat transfer studies; (13) transport phenomena near a liquid-vapor interface; and (14) fundamental studies of corrosion processes. Investigations are being carried on at the Berkeley, Los Angeles and San Diego Campuses.

- (g) Detailed results may be obtained from the progress reports and publications listed under (h) below. This project has been active since 1951-52 and previous summaries have listed all reports prior to July 1963.
- (h) The following reports and publications have been issued during the period since July 1963 and summarize the work to date:

UNIVERSITY OF CALIFORNIA AT LOS ANGELES:
 "Electrochemical and Surface Studies of Zn and InSb Single Crystals," D. Chance and K. Nobe, Dept. of Engineering Report No. 63-49, 79 pp., Sept. 1963.
 "The Use of Thin, Capillarity Controlled, Gaseous Diffusion Gaps in Saline Water Demineralization," Thomas Thorsen, Dept. of Engineering Report No. 63-50, 105 pp., October 1963.
 "Preliminary Economic Study U.C.L.A. Reverse Osmosis Process for Brackish Water Desalination," J. W. McCutchan, S. Loeb, P. A. Buckingham, A. W. Ayers, Dept. of Engineering Report No. 63-62, 60 pp., Dec. 1963.
 "A Study of Criteria for the Semipermeability of Cellulose Acetate Membranes to Aqueous Solutions," Rodney Blunk, Dept. of Engineering Report No. 64-28, June 1964.
 UNIVERSITY OF CALIFORNIA, BERKELEY**
 "1963 Progress Report, Berkeley and San Diego Campuses," by E. D. Howe et al, Sea Water Conversion Laboratory Report No. 64-1, 55 pp., Feb. 1964.
 "Electrodialytic Treatment of Irrigation Drainage Water--Preliminary Study," by W. K. Baker, S. A. Weiner and E. D. Howe, Sea Water Conversion Laboratory Report No. 64-2, 34 pp., June 1964.
 "Condensing Heat Transfer in Stream-Air Mixtures in Turbulent Flow," by P. B. Stewart, I&EC Process Design & Development, Vol. 3, p. 48, Jan. 1964.
 "Polarization Characteristics of Electrodialytic Demineralization," by S. A. Weiner, I&EC Process Design & Development, Vol. 3, p. 126, April 1964.
 "Direct Contact Heat Transfer for Sea Water Evaporation," by C. R. Wilke, Chemical Engineering Progress, Vol. 59, No. 12, pp. 60-75, Dec. 1963.
 "The Desalting of Sea Water," by E. D. Howe, SPAN, Vol. 7, No. 2, pp. 94-96, 1964.
 "Solar Distillation on the Pacific Atolls", by E. D. Howe, South Pacific Bulletin, Vol. 14, No. 2, pp. 57-59, April 1964.
 *Requests for copies should be directed to: Institute of Industrial Cooperation, Dept. of Engineering, Univ. of California, Los Angeles, Calif.
 **Requests for copies should be directed to: Sea Water Conversion Laboratory, Univ. of California, 1301 South 46th Street, Richmond, California.

(2265) FORCES ON ACCELERATED CYLINDERS.

- (b) National Science Foundation; laboratory project.
- (c) Prof. A. D. K. Laird, 109 Mechanics Bldg., Univ. of California, Berkeley, Calif. 94720.
- (d) Experimental and theoretical, basic research
- (e) Measurement and prediction of drag coefficients and flow configurations about cylinders during accelerated motion in fluids as related to wave forces as cylinders including effects of support flexibility.
- (h) "Wave Forces on Piling" by A. D. K. Laird, Inst. Eng. Res. Report HFS-64-1, June 1964, for U. S. Naval Civil Engrg. Lab., Port Hueneme, California.

(2505) EFFECT OF SEDIMENT DISTRIBUTION IN STREAM CHANNELS.

- (b) University project.
- (c) Prof. H. A. Einstein, Dept. of Civil Engineering, Univ. of California, Berkeley, Calif. 94720.
- (d) Experimental; basic research.

- (e) Alluvial flows in channels with artificially secured banks are studied systematically for their tendency to meander as expressed by the development of alternate bars. It is the aim of this study to develop criteria for stability.
 - (f) Concluded.
 - (g) It was found empirically that it is practically impossible to create the characteristic alternate bars based on reversing secondary currents in laboratory flumes with smooth vertical banks. Under the same average flow and sediment conditions in the same flumes the alternate bars appear if rough sloping banks are substituted. The bank friction is used to explain the creation of the bars.
 - (h) "A Study on Meandering in Straight Alluvial Channels," by H. A. Einstein and H. W. Shen (submitted for publication).
- (3675) CLAY TRANSPORT.
- (b) National Science Foundation and California State Water Resources Center.
 - (c) Prof. H. A. Einstein, Dept. of Civil Engineering, Univ. of California, Berkeley, Calif. 94720.
 - (d) Experimental, basic research.
 - (e) Determination of the friction factor of flocculated clay deposits using mud from San Francisco Bay.
 - (f) Continued.
 - (g) The 1000-ft channel is used to measure the friction characteristics of mud deposited in flowing salt water. The past experiments indicate the surface of the deposit to be rather smooth and to show a roughness factor independent of the flow velocity for steady flow. In unsteady flow it has the tendency of becoming rougher.
- (3677) ANNULAR NOZZLE GROUND EFFECT MACHINE.
- (b) Office of Naval Research, Dept. of the Navy.
 - (c) Prof. R. L. Wiegell, Dept. of Civil Engrg., Univ. of Calif., Berkeley, California 94720.
 - (d) Experimental; applied research.
 - (e) Airborne vehicles supported by annular jets have a lift considerably in excess of that due to the jet momentum when operating in a region close to the ground. The dynamic lift, bending moment, wave resistance, base pressures, and intake pressures are being measured for such a vehicle operating over both calm water and water with surface gravity waves present.
 - (f) Completed.
- (3678) OCEAN SEWER OUTFALLS.
- (b) U. S. Public Health Service.
 - (d) Basic research.
 - (e) This study is concerned with the various phenomena involved in the diffusion of sewage at the discharge end of an ocean sewer outfall.
 - (f) Completed.
 - (g) Recent work has been done on the mixing of warm water jets being discharged horizontally at the surface of a body of water.
 - (h) "Surface Discharge of Horizontal Warm Water Jet" by Yuan Jen, R. L. Wiegell and Ismail Mobarek, IER, Tech. Rept. HEL 3-3, 40 pp., Dec. 1964.
- (4077) NEARSHORE SEDIMENT MOVEMENT.
- (b) National Science Foundation.
 - (d) Experimental (laboratory and field).
 - (e) The objective of this investigation is to determine the overall sand balance for selected localities and to explain changes quantitatively. Special consideration is given to sediment conditions at the mouths of large sediment-carrying rivers, submarine canyon heads, and major headlands.
- (f) Completed.
 - (h) "Sand Movement along a Portion of the Northern California Coast," by John Cherry, Univ. of Calif. Hyd. Engrg. Laboratory Report No. HEL-4-4, 1964.
- (4078) BEACH BACKGROUND RADIOACTIVITY.
- (b) Atomic Energy Commission, Washington, D. C.
 - (d) Field observations and theoretical considerations.
 - (e) Purpose of project is to measure variations in background radioactivity of beaches along the California Coast with the object of determining the normal background, its seasonal variations and variation in radioactivity from place to place at any one time.
 - (f) Completed.
 - (g) The dilution in concentration of naturally radioactive sediments away from a source has proved of value in establishing the predominant direction of littoral drift.
 - (h) "Radiometric Determination of Thorium in Coastal Sands for Tracing Littoral Movement" by Zaven Tashjian, John Cherry, George Gordon, and Moshe Gablinger, Univ. of Calif. Hyd. Engrg. Lab. Report No. HEL-5-3, Aug. 1964.
- (4081) RECHARGE OF WASTES IN UNDERGROUND FORMATIONS.
- (b) Livermore Radiation Lab., Livermore, Calif.
 - (d) Experimental; basic and applied research.
 - (e) This study is designed to evaluate the hydraulics of fluid flow from a surface basin into underlying aquifers. Results are expected to assist in field studies of disposal of industrial wastes, brines, and radioactive materials.
 - (f) Completed.
- (4082) CAVITATION IN A VENTURI.
- (b) Laboratory project.
 - (c) Prof. H. W. Iversen, Dept. of Mech. Engrg., University of Calif., Berkeley, Calif. 94720.
 - (d) Experimental and theoretical basic research.
 - (e) Macroscopic nature of cavitation formation and collapse with inter-relationships of head losses on collapse and with liquids of different vaporization properties.
 - (f) Suspended.
- (4562) ANALYSIS OF NONLINEAR SYSTEMS.
- (b) Laboratory project.
 - (c) Prof. J. A. Harder, Hesse Hall, Univ. of California, Berkeley, Calif. 94720.
 - (d) Theoretical; basic research.
 - (e) Given a sufficiently long record of the input and output of a stationary system that may include nonlinearities, the purpose is to develop a predictor for arbitrary inputs.
 - (g) Computer program is written that has enabled close prediction of the output of an experimental nonlinear system to a sine wave having an amplitude and frequency well within the limits of the random input used to develop the predictor.
- (4565) MATHEMATICAL MODELS FOR FLOOD ROUTING.
- (b) U. S. Corps of Engineers, Omaha District Office.
 - (c) Prof. J. A. Harder, Hesse Hall, Univ. of California, Berkeley, Calif. 94720.
 - (d) Theoretical; basic research.
 - (e) Various models are being fitted to experimental floods induced by spillway releases from reservoirs on the Missouri River.
 - (g) Principal limitation has been found to be accuracy of channel data.
- (4568) SIGNIFICANCE OF VORTICITY IN TURBULENT FLUID FLOWS.
- (b) University project; thesis.
 - (c) Prof. H. A. Einstein, Dept. of Civil Engrg.,

- Univ. of California, Berkeley, Calif. 94720.
- (d) Theoretical.
 - (e) A basic attempt to define turbulence.
 - (f) Terminated.
 - (g) A function was introduced which may be described as the "curvature" of the velocity field. This function is able to describe the energy dissipation of the flow while vorticity alone cannot do it.
 - (h) "The Significance of Vorticity, Vortex Motion and Dissipation in Turbulent Fluid Flow," Ph.D. thesis by Lyle F. Mockros, Univ. of Calif., Berkeley, June 1962.
- (4929) AQUIFER ANALYSIS BY SLUG TESTS OF WELLS.
- (b) Laboratory project.
 - (d) Experimental; applied research.
 - (e) Study of the limitations, procedural problems, and validity under various field conditions of the slug test method of evaluating aquifer constants.
 - (f) Completed.
 - (h) "Determination of Aquifer Permeability by Slug Tests of Wells," by K. Ho and D. K. Todd, Hydraulic Laboratory, Univ. of Calif., Berkeley, Water Resources Center Contribution No. 93, 41 pp., August 1964.
- (4930) COASTAL SAND MOVEMENT.
- (b) Corps of Engineers, U. S. Army, Coastal Engineering Research Center.
 - (d) Experimental; laboratory and field.
 - (e) This investigation is concerned with the transportation of sand by both wind and waves.
 - (h) "Sand Movement by Wind" by P. Y. Belly, U. S. Army Coastal Engin. Res. Center, Tech. Memo. No. 1, Wash., D. C., Jan. 1964. "Transportation of Bed Material due to Wave Action," by George Kalkanis, U. S. Army Coastal Engin. Res. Center, Tech. Memo No. 2, Wash., D. C., Feb. 1964. "Calculation Procedure for Sand Transport by Wind on Natural Beaches" by A. L. Kadib, U. S. Army Coastal Engin. Res. Center, Misc. Paper No. 2-64, Wash., D. C., April 1964. "Sediment Transport by Waves and Currents" by M. M. Abou-Seida, Univ. of Calif. Hyd. Engin. Lab. Report No. 2-7, May 1964. "Study of Sand Movement by Wind" by R. Kawamura (A Translation), Univ. of Calif. Hyd. Engin. Lab. Report No. HEL-2-8, June 1964. "Suspension of Cohesive Sediment by Wind-Generated Waves" by M. R. Alishahi and R. B. Krone, Univ. of Calif. Hyd. Engin. Lab. Report No. HEL-2-9, August 1964. "The Erosional and Depositional History of a Portion of the Coast of Northern California" by Claude R. Minard, Jr., Univ. of Calif. Hyd. Engin. Lab. Report No. HEL-2-10, Sept. 1964.
- (4932) GROUND WATER BASIN MANAGEMENT.
- (b) Laboratory project.
 - (d) Experimental and theoretical; applied research.
 - (e) Study of the physical conditions within a basin so that ground water levels at any point can be predicted for any future time for given recharge and discharge conditions. Subsequently, study of alternate methods for operating the basin to obtain an economically optimal system.
- (4933) HYDRAULIC SYSTEMS ANALYSIS.
- (b) California Department of Water Resources.
 - (c) Prof. J. A. Harder, Hesse Hall, Univ. of California, Berkeley, Calif. 94720.
 - (d) Experimental; applied research and design.
 - (e) Analog model and digital computer methods are being used to predict salinity, tidal amplitudes, tidal elevations, and fresh water flows in the Sacramento-San Joaquin Delta Region.
- (4934) WAVE DIFFRACTION AND REFRACTION.
- (b) Corps of Engineers, U. S. Army, Coastal Engineering Research Center, Washington, D. C.
 - (c) Prof. R. L. Wiegel, Univ. of California, Berkeley, Calif. 94720.
 - (d) Experimental; basic research.
 - (e) Determination by model tests the diffraction and refraction characteristics of wind waves. Also, model studies of the "Mach-stem" equivalent of water waves.
 - (g) IBM 7090 program developed for computing wave diffraction coefficients at semi-infinite breakwater. Work finished on computing two dimensional wave spectra in model basin.
 - (h) "Water Wave Equivalent of Mach-Reflection," by R. L. Wiegel, IER Tech. Rept. HEL 1-4, 27 pp., August 1964.
- (5435) SEAWALL OVERTOPPING BY WIND WAVES.
- (b) Laboratory project.
 - (d) Experimental.
 - (e) The intensity of overtopping of a seawall by wind waves was investigated for various water depths in front of the seawall.
 - (f) Completed.
- (5436) BAR RESISTANCE IN DEGRADING CHANNELS.
- (b) Laboratory research, supported by California State Water Resources Center.
 - (c) Prof. H. A. Einstein, Dept. of Civil Engrg., Univ. of California, Berkeley, Calif. 94720.
 - (d) Experimental, Ph.D. thesis.
 - (e) An equilibrium flow is established and measured. Then the same flow is repeated with reduced sediment feed and the effect on the flow is observed.
 - (g) Only minor deviations have been observed, indicating that slowly degrading flows may be calculated like equilibrium flows. Only few sediment conditions have been tested to date.
- (5437) DEPOSIT OF SILT IN A GRAVEL BED BY WATER FLOWING OVER THE BED.
- (b) U. S. Bureau of Reclamation.
 - (c) Prof. H. A. Einstein, Dept. of Civil Engrg., Univ. of California, Berkeley, Calif. 94720.
 - (d) Experimental, basic research.
 - (e) It is proposed to determine the rate at which fine sediment is deposited in artificial spawning grounds for salmon and other fish. It is proposed to determine the extent of maintenance for such works. The sediment carrying flow is recirculated over gravel beds in laboratory flumes.
- (5438) SHAPE OF CROSS SECTIONS IN RIVER BENDS.
- (b) Laboratory research, supported by the California State Water Resources Center.
 - (c) Prof. H. A. Einstein, Dept. of Civil Engrg., Univ. of California, Berkeley, Calif. 94720.
 - (d) Experimental with statistical analysis, Ph.D. thesis.
 - (e) A circular flume has been constructed in which various flows are established and cross sections established. The cross sections are statistically described by a minimum of parameters and the change of these parameters established in terms of the flow and sediment parameters. River sections are equally analyzed.
- (5439) WAVE FORCES.
- (b) Corps of Engineers, U. S. Army, Coastal Engineering Research Center, Wash., D. C.
 - (c) Prof. R. L. Wiegel, Univ. of California, Berkeley, Calif. 94720.
 - (d) Experimental and theoretical; basic research.
 - (e) Determine by model tests the forces exerted by waves on coastal structures. Theoretical studies of statistical properties of wave forces.

- (h) "Wave Forces on a Dock," by Osman A. El-Ghamry, IER Tech. Rept. HEL 9-1, 201 pp., October 1963.
 "Wave Forces on Square Piling," by Michael D. Astin, IER Tech. Rept. HEL 9-2, 28 pp., June 1964.
 "The Statistical Distribution of Ocean Wave Forces on Vertical Piling," by Leon E. Borgman, IER Tech. Rept. 9-3, 39 pp., May 1964.
 "Wave Force Program," by Ralph H. Cross, IER Tech. Rept. HEL 9-4, 26 pp., Sept. 1964.

UNIVERSITY OF CALIFORNIA, BERKLEY, Dept. of Naval Architecture.

(3026) SHIP RESISTANCE IN UNIFORM WAVES AS A FUNCTION WAVE STEEPNESS.

- (b) David Taylor Model Basin, Dept. of the Navy.
 (c) Mr. O. J. Sibul, Room 224, Bldg. T-3, Univ. of Calif. Berkeley, California 94720.
 (d) Experimental.
 (e) Experiments were performed to study the resistance of ships in uniform waves. Motions as well as resistances were measured in more than 2,500 individual tests. The transfer functions necessary to predict the added resistance in irregular seaways were calculated from the experimental results.
 (f) Completed.
 (g) The results indicate that the added resistance depends upon the block coefficient, the speed of the ship and the steepness of the waves. It has a maximum in the vicinity of the maximum motions and decreases again for the higher speeds. The added resistance is higher per unit displacement for smaller block coefficients.
 (h) "Ship Resistance in Uniform Waves" by O. J. Sibul, Univ. of Calif., Institute of Eng. Research Report No. NA-64-1, Jan. 1964.

(4083) DYNAMIC INTERACTION BETWEEN SHIPS.

- (b) Office of Naval Research, Dept. of the Navy.
 (c) Prof. J. R. Paulling, Room 224, Bldg. T-3, Univ. of Calif., Berkeley, California. 94720
 (d) Theoretical and experimental.
 (e) The linearized equations of motion for two ships operating on parallel courses are formulated. Coefficients appearing in these equations are being evaluated by captive model techniques. Analog and digital means of solving the equations are being studied.
 (g) Sinusoidal motion generator was used to evaluate velocity and acceleration derivatives for each of the individual models of the ship without the other model being present. Experiments are under way in which interaction forces and moments between two models are measured.

(4084) SHIPS OF MINIMUM RESISTANCE.

- (b) Office of Naval Research, Dept. of the Navy.
 (c) Prof. J. V. Wehausen, Room 221, Bldg. T-3, Univ. of Calif., Berkeley, California. 94720
 (d) Theoretical applied research.
 (e) The general aim of this work is to find computer designed ships of minimum "total" resistance, subject to various restraining conditions. Here "total" resistance means the Michell wave resistance plus the equivalent flat-plate frictional resistance. Two cases have been studied up to now. In one the afterbody was given and an optimum forebody was found. In the other, the volumetric coefficient and draft/length ratio were fixed and the optimum, necessarily

symmetric, ship found. The computations were carried out on an IBM 7094 and the lines themselves were also drawn with computer control. Froude numbers varied from 0.224 to 0.5. Resistance measurements have been carried out on the hull from each family corresponding to Froude number 0.316. Further computations and experiments are under way.

- (h) "Experiment Data for Two Ships of 'Minimum' Resistance" by Lin, W. C.; Pauling J. R.; Wehausen, J. V., Univ. of Calif., Institute of Eng. Research Report No. NA-64-8, August 1964.

(4570) PRESSURE DISTRIBUTION ON SEMI-SUBMERGED OSCILLATING BODIES.

- (b) David Taylor Model Basin, Department of the Navy.
 (c) Prof. J. R. Paulling, Room 224, Bldg. T-3, University of California, Berkeley 4, Calif.
 (d) Experimental and theoretical.
 (e) To determine the response of a floating body in a seaway, it is necessary to know the magnitudes and phases of hydrodynamic forces and moments acting on this body. In the linearized analysis the total pressure at any point takes the form of two terms: (a) exciting pressure dependent upon the waves only; (b) pressure dependent upon the geometry and motion of the body and independent of the waves. These two terms are being measured on: (1) A prolate spheroid; (2) A ship-like form. First the models are attached rigidly to the dynamometers, towed in waves and the pressure distribution, total forces and moments measured. Then the models are oscillated sinusoidally in still water and again the pressure distribution, total force and moment measured. The results will be compared with theoretical calculations.
 (g) Both the models have been tested in still water as well as in waves. The results indicate that the wave forces and moments follow the general trend as predicted by Krylov's Theory. For the oscillating models in still water, the longitudinal distribution of virtual mass and damping have been determined experimentally.
 (h) "Heaving Forces and Pitching Moments on a Semi-Submerged and Restrained Prolate Spheroid Proceeding in Regular Head Waves" by Lee, C. M., Univ. of Calif., Institute of Eng. Research Report No. NA-64-2, Jan. 1964. Another report in preparation.

(4971) SHIP RESISTANCE IN IRREGULAR WAVES.

- (b) David Taylor Model Basin, Dept. of the Navy.
 (c) Mr. O. J. Sibul, Room 224, Bldg. T-3, Univ. of Calif., Berkeley, California. 94720
 (d) Experimental; applied research.
 (e) The previous resistance measurements of ship models in uniform waves will be used to predict the total added resistance in irregular waves of known spectral content. The predictions will be compared with experiments in irregular waves of various spectral contents and severity, combined with a number of model speeds.
 (g) Resistance was measured in waves having 2 components only. The resistance in each of the component wave was determined in separate experiments. The measurements indicate that the total resistance in the combined wave is somewhat higher than the linear addition predicts.
 (h) In preparation.

(4972) STUDY OF A SPAR SHIP.

- (b) Bureau of Ships, Dept. of the Navy.
 (c) Prof. John R. Paulling, Jr., Room 224, Bld. T-3, Univ. of Calif., Berkeley, Calif.
 (d) Experimental; theoretical, applied research.
 (e) To study the hydrodynamic characteristics of a spar ship a cylindrical model with a cross

section made up by two circular arcs was tested in still water as well as in waves. The length-draft ratio of the model was 0.25 and the beam-draft ratio 0.05. The model was tested: (1) for resistance in still water as well as in waves; (2) wave forces and moments on restricted model; (3) motions for the free model in uniform waves; (4) model was oscillated in still water and the virtual mass and damping calculated. An attempt was made to calculate the still-water resistance theoretically.

- (f) Completed.
- (h) "Laboratory Investigation of a Spar Ship" by Karhan, K., Univ. of Calif., Institute of Eng. Research Report No. NA-64-7, June 1964.

(5301) SHIP SLAMMING.

- (b) U. S. Dept. of Commerce, Maritime Administration.
- (c) Prof. H. A. Schade, Dept. of Naval Architecture, Univ. of Calif., Berkeley, Calif.
- (d) Experimental and theoretical; applied research.
- (e) The purpose of the project is to investigate the impact loads (pressures) caused by slamming and the response of the ship structure to these loads. The capacity of the testing equipment is as follows: (a) 1/4 scale models; (b) total model weights up to 40,000 lbs; (c) drop height up to 10 ft. above the still water surface.
- (g) Preliminary results for an extra stiff flat model indicate that: (a) For lower drop heights the peak pressure varies nearly as the square of the impact velocity; (b) the pressure is proportional to the deceleration (for the range 10 to 30 g).
- (h) Report in preparation.

THE CATHOLIC UNIVERSITY OF AMERICA, Department of Civil Engineering.

(3030) TRANSIENT FLOW THROUGH POROUS INCOMPRESSIBLE MEDIA WITH VARIOUS BOUNDARY CONDITIONS.

- (b) Experimental part was supported by the National Research Council of Canada.
- (c) Dr. B. S. Browzin, Professor of Civil Engrg., The Catholic University of America, Wash., D. C. 20017.
- (d) Experimental and theoretical; basic research.
- (e) The unsteady laminar flow was reproduced by a highly viscous liquid flowing between closely spaced translucent plates on a number of models with geometric boundaries representing various types of earth dams on impervious foundations and earth massives crossed by open channels. Experimental part concerning earth dams and earth massives on impervious foundations completed. The theoretical part of the research completed for the case of rapid drawdown in homogeneous dams. The theoretical research of cases of gradual drawdown, of non-homogeneous dams, of tailwater condition, and the drawdown in canals is intended to be continued this year.
- (g) An approximate function, relating by dimensionless parameters, the shape and the position of free surface of flow through the earth dam, following rapid reservoir drawdown, to the geometry of the dam, was obtained theoretically and confirmed by experiments.
- (h) "Nichtstationäre Sickerströmungen in homogenen Erddämmen und Erdkörpern," pp. 280 Doctoral dissertation at the Rheinisch-Westfälische Technische Hochschule Aachen, 1961. The book is available at the library of the National Research Council of Canada, Ottawa 2, Ontario.

(3031) THE VARIATION OF HYDROLOGIC FACTORS AND THEIR INFLUENCE ON RIVER REGIMES IN THE GREAT LAKES-ST. LAWRENCE DRAINAGE AREA.

- (b) Laboratory project.
- (c) Dr. B. S. Browzin, Professor of Civil Engrg., The Catholic University of America, Wash., D. C. 20017.
- (d) Basic research.
- (e) Research is based on long range flow and meteorologic record. Flow and precipitation data on U.S. and Canada stations were statistically investigated in order to obtain river regime characteristics.
- (f) Completed.
- (g) Classified discharges for long range gauging stations are calculated. Characteristic parameters for river classification of the area are obtained, water-balance in the basin is calculated; average, maximum and minimum run-off for the period of available observations is analysed.
- (h) "Seasonal Variations of Flow and Classification of Rivers in the Great Lakes - St. Lawrence Basin". Proceedings of the 7th Conference on Great Lakes Research, Ann Arbor, March 1964. "Donnees Fondamentales sur l'Hydrologie des Rivières dans le Bassin du Saint-Laurent", pp. 448. Dissertation of the "Doctorat d'Etat es Science" at the University of Grenoble. The book is available from the author.

(5258) ANALYTICAL METHODS OF CALCULATION OF THE UPLIFT ACTING ON GRAVITY DAMS BUILT ON PERVIOUS BASES.

- (b) Laboratory project.
- (c) Dr. B. S. Browzin, Professor of Civil Engineering. The Catholic University of America, Wash., D. C. 20017.
- (d) Theoretical.
- (e) Mathematical solution from recent foreign literature is collected, summarized and presented primarily for dam designers.
- (f) Completed.
- (h) "Nouvelle Methode d'Application de Quelques Fonctions de la Variable Complexe aux Calculs des Sous-Pressions Agissant sous les Ouvrages de Retenue". Manuscript.

COLORADO STATE UNIVERSITY, Civil Engineering Section.

(55) SNOW COURSE MEASUREMENTS AND FORECAST ANALYSIS.

- (b) Soil Conservation Service, Colorado Agric. Experiment Station.
- (c) Mr. Jack N. Washichek, Snow Survey Supervisor, Agricultural Engineering Section.
- (d) Field investigations; applied research.
- (e) Systematic measurements of depth and water content of snow are being made at high elevations in Colorado and New Mexico mountain areas for the purpose of forecasting the runoff of the principal rivers in the interest of irrigation, power, domestic supplies, and other uses. The use of electrical resistance soil moisture units is being tested to determine a factor of soil moisture deficiency for water supply forecast purposes. Most of the major basins now have two or more soil moisture stations installed. Correlation of soil moisture and runoff is now being developed with the hope that this information can be used as a factor in forecasting.
- (g) Forecasts are now being issued at forty-four gaging stations in Colorado and New Mexico. As forecast procedures improve, additional streams will be forecasted and other areas of potential power and irrigation development will be investigated on the Colorado, San Juan, Animas and Arkansas Rivers.
- (h) Colorado Agricultural Experiment Station General Series Papers Nos. 780, 781, 782, and 783 covering monthly snow reports for all of Colorado and New Mexico. Nine small basin reports and one two-state

- bulletin covering the South Platte River watershed; Arkansas River watershed; Rio Grande watershed in Colorado; Rio Grande watershed in New Mexico; Dolores River watershed; San Juan and Animas River watershed; Gunnison River watershed; Colorado River watershed; Yampa, White and North Platte River watershed; Lower South Platte River watershed. Supplemental reports are issued January 1, May 15, and June 1.
A summary of all back data was issued this fall.
A bulletin entitled "Snow Surveys in Colorado" will be ready for distribution in December. This is co-authored by Norman A. Evans, Homer J. Stockwell and Jack N. Washichek.
- (821) GROUND WATER FLUCTUATIONS AND THEIR RELATION TO PUMPING.
- (b) Colorado Agricultural Experiment Station.
 - (c) Mr. M. M. Skinner, Assistant Civil Engineer.
 - (d) Field investigation; applied research.
 - (e) Semi-annual measurements of the depth to the water table in approximately 610 observation wells are presently being obtained. The Ground Water Branch of the U. S. Geological Survey, Denver, Colorado are cooperating in furnishing measurements for about 130 wells. The observation wells are primarily existing irrigation wells in the South Platte and Arkansas River Basins, the High Plains area of eastern Colorado and the San Luis Valley. Electrical Power and Natural Gas Consumption data are compiled and estimates of groundwater pumpage made. The purpose of the project is to detect areas of ground-water depletion, to develop relationships between gross pumpage and respective ground-water reservoir storage volume changes, and acquire basic data for ground-water studies in the various areas of Colorado.
 - (g) Ground-water levels of the spring of 1964 are generally down as compared to the spring of 1963 in the South Platte and Arkansas River Basins and the San Luis Valley. Considerable ground-water pumpage is continuing in the High Plains area of eastern Colorado with some increase in pumping lifts resulting. Reported electrical power consumption by electrical pumping during 1963 in Colorado amounted to approximately 190,000,000 kilowatt hours for 9295 pumping units.
 - (h) "Artificial Ground-Water Recharge in the Prospect Valley Area, Colorado," Agricultural Experiment Station, General Series 792, M. M. Skinner, Nov. 1963.
"Colorado Ground-Water Levels - Spring 1964," CER64MMS9, May 1964, by M. M. Skinner.
- (2770) TURBULENCE STUDIES IN LIQUID USING ELECTROKINETIC PHENOMENON.
- (b) National Science Foundation.
 - (c) Dr. J. E. Cermak.
 - (d) Experimental research; basic research, doctoral thesis.
 - (e) The primary objective of the study is to determine the interaction between velocity fluctuations produced by turbulence in the liquid flow and electrokinetic potential fluctuations generated at a liquid-solid interface. Knowledge gained by this study will be applied to developing techniques for measuring turbulence characteristics in liquids.
 - (g) Probes constructed with electrode pairs have been used to measure the distribution of turbulence intensities (three components) and the turbulent shear stress across a diameter of a circular pipe. The distribution measured in water agree with those obtained by Laufer in air using a hot-wire anemometer.
 - (h) "Electrokinetic-Potential Fluctuations Generated by Jet Impingement", by L. Duckstein and J. E. Cermak. Journal of Heat and Mass Transfer, Vol. 7, pp. 159-167, 1964.
- (2902) DEVELOPMENT IMPROVEMENT OF WATER MEASURING DEVICES.
- (b) Northern Plains Branch, Soil and Water Conservation Research Division, ARS, USDA.
 - (c) E. Gordon Kruse, Agricultural Engineer.
 - (d) Experimental, laboratory investigation; applied research, operation and development.
 - (e) New and improved devices and techniques for measurement of irrigation water are being developed. Specific objectives are
(1) Design, evaluation and calibration of trapezoidal measuring flumes, (2) Design and evaluation devices for combined water measurement and control, and (3) Development of a probe using the drag on a suspended wire to indicate total flows, velocity distributions and forces on sediment particles.
 - (g) The development of trapezoidal measuring flumes is continuing. Flumes with cross-sections corresponding to common slipform concrete ditches have been designed and calibrated.
Two shapes of broadcrested weirs were evaluated with respect to their ability to measure flows accurately under high degrees of submergence.
- (3398) TURBULENT DIFFUSION IN SHEAR FLOW.
- (b) National Institute of Health, Public Health Service, U. S. Dept. of Health, Education and Welfare, Washington, D. C.
 - (c) Dr. J. E. Cermak.
 - (d) Experimental research; basic research, doctoral thesis.
 - (e) The objective of this project is to determine the influence of geometrical factors (land surface roughness, topography, structures), and thermal and aerodynamical factors (turbulence intensity and scale) upon atmospheric diffusion of heat and mass. "Laws of modeling" or "similitude parameters" are sought by obtaining detailed data under various conditions in the wind tunnel and by comparing them with similar data now existing for the atmospheric prototype.
 - (g) Application of a hypothesis of Lagrangian similarity to particle motions in a turbulent shear flow near a solid boundary has yielded similarity parameters and relationships between them which correlate the wind-tunnel diffusion data and available diffusion data obtained in the atmospheric surface layer.
 - (h) "Wind Tunnel Modelling of Atmospheric Diffusion," by R. C. Malhotra and J. E. Cermak, Journal of Geophysical Research, Vol. 68, No. 8, April 1963.
"Study of Diffusion from a Line Source in a Turbulent Boundary Layer," by M. Poreh and J. E. Cermak; International Journal of Heat and Mass Transfer, Vol. 7, 1964, pp. 1083-1095.
"Mass Diffusion in Neutral and Unstably Stratified Boundary-Layer Flows," by R. C. Malhotra and J. E. Cermak; International Journal of Heat and Mass Transfer, vol. 7, pp. 169-186, 1964.
"Lagrangian Similarity Hypothesis Applied to Diffusion in Turbulent Shear Flow," J. E. Cermak; Journal of Fluid Mechanics, Vol. 15, pp. 49-64, 1963.
"Characteristics of Diffusion Plumes from a Point Source within a Turbulent Boundary Layer," by K. S. Davar, and J. E. Cermak; International Journal of Air and Water Pollution, Vol. 8, pp. 339-354, Dec. 1963.
- (3400) HYDRAULICS OF SUB-CRITICAL FLOW IN SMALL, ROUGH CHANNELS.
- (b) Colorado Agricultural Experiment Station and Agricultural Research Service, U. S. Department of Agriculture.
 - (c) Dr. Norman A. Evans, Head, Dept. of Agricultural Engineering.
 - (d) Theoretical, laboratory experiment.
 - (e) Both laboratory and field studies have been conducted. A tilting flume was used in the

- laboratory, and a portable truss to carry a measuring carriage was used in the field. The purpose is to relate roughness in small channels to flow resistance.
- (g) Resistance to flow in small channels does not follow the same relationships established for large channels. The standard deviation of peak to valley heights was found to be a significant parameter, and a spectral density description of roughness is being tested.
- (h) "Hydraulics of Surface Irrigation," by Norman A. Evans, 1962. See Project No. 4296, page 112, Agricultural Research Service.
- (3704) DEVELOPMENT AND USE OF COLORADO BENTONITE IN SEALING IRRIGATION CANALS AND RESERVOIRS.
- (b) State of Colorado.
- (c) R. D. Dirmeyer, Jr., Project Leader
- (d) Field investigation; applied research and development.
- (e) The work consists of three stages: (1) Inventory of clay deposits in Colorado with emphasis on those potentially usable in sealing canals and reservoirs. (2) Laboratory evaluation of clays from (1) above. (3) Field trials in canals and reservoirs with best clays found in (1) and (2) and evaluation of sealing results (initial and with time).
- (g) Inventory and Testing -- A total of 321 samples of Colorado clays were collected and tested in the laboratory. Development of Deposits and Field Trials -- Eight deposits have been developed commercially. Clays from these deposits were used in 132 trials in canals and ponds during the three year project.
- (h) A final report of the three-year project was prepared: "Evaluation of Colorado Clays for Sealing Purposes," by R. D. Dirmeyer and M. M. Skinner, CSU Tech. Bull. 83, May 1964.
- (3708) INVESTIGATIONS TO DEVELOP WIND TUNNEL TECHNIQUES FOR MEASURING ATMOSPHERIC GASEOUS DIFFUSION IN MODEL VEGETATIVE SURFACES.
- (b) Agricultural Research Service, U.S. Dept. of Agriculture.
- (c) Dr. J. E. Cermak, Professor of Engineering Mechanics and Civil Engineering; and Mr. E. J. Flate, Associate Professor.
- (d) Laboratory research; basic research, applied research for thesis (doctoral).
- (e) Diffusion of a gas (ammonia) into and out of a model vegetated plane area of a wind tunnel test section floor is to be studied. Using a test section 80 ft long and 6 x 6 ft in cross-section the turbulent boundary layer in which diffusion occurs will be several times thicker than the vegetation height. Using the basic equations of fluid mechanics, an attempt will be made to establish criterion for application of the model data to prototype conditions. The criterion developed will be checked using field data being obtained at Cornell University by the Agricultural Research Service.
- (f) Completed.
- (g) A study of diffusion from a line source into a boundary layer over a flat, smooth plate has been completed. Results show that the diffusion pattern can be separated into different zones, according to distances from the source in which different similarity laws are valid for the diffusion process.
- (h) "Study of Diffusion from a Line Source in a Turbulent Boundary Layer"; International Journal of Heat and Mass Transfer, Vol. 7, pp. 1083-1095, 1964, by M. Forch and J. E. Cermak.
- (4099) WAKE CHARACTERISTICS FOR BODIES OF REVOLUTION WITH MOMENTUM ADDITION.
- (b) David Taylor Model Basin.
- (c) Dr. L. V. Baldwin, Acting Dean of Engineering.
- (d) Experimental, theoretical; basic research.
- (e) Turbulent and mean flow characteristics of wakes formed behind axisymmetric and elliptical bodies have been studied experimentally in a wind tunnel using hot-wire anemometers. Theoretical studies have lead to explanations of all observed phenomena.
- (h) "Comments on Three Dimensional Effects in Viscous Wakes", Y. H. Kuo and L. V. Baldwin, AIAA Journal, Vol. 2, No. 6, pp. 1163-64 (June 1964). "Decay of Turbulence in Axisymmetric Wakes", N. H. C. Hwang and L. V. Baldwin, Paper accepted for publication in ASME Transactions (early 1965).
- (4100) ANALYSIS OF RIVER FLOW AND PRECIPITATION SEQUENCES.
- (b) National Science Foundation.
- (c) Dr. V. M. Yevjevich, Professor of Civil Engineering.
- (d) Theoretical; basic research.
- (e) The study of fluctuations of river flow and precipitation has been continued.
- (g) Fluctuations of flow and precipitation on an annual basis is a stochastic process with water carryover as the main factor of time dependence.
- (h) "Theoretical Frequency Functions of Best Fit to Distributions of Annual Precipitations and Mean Annual River Flows," by R. Markovic.
- (4101) UNSTEADY FREE SURFACE FLOW IN A LARGE STORM DRAIN.
- (b) U. S. Bureau of Public Roads and U. S. Public Health Service.
- (c) Dr. V. M. Yevjevich, Professor of Civil Engineering.
- (d) Experimental and theoretical; basic research.
- (e) A 825-ft long, 36-in. diameter conduit, movable on 43 supports on a hillside, is used as the main experimental facility to simulate and record free surface waves in pipes. The same waves are computed by using a digital computer and then a comparison is made. The ultimate purpose is a development of a set of routing methods to suit the desired accuracy and the quality of the initial and boundary data. The experimental part of the hydraulic study has progressed sufficiently during 1964 so that the analysis of data is underway.
- (g) The analytical study for directing the research is being completed.
- (4106) GROUND-WATER RESERVOIR MANAGEMENT.
- (b) Colorado Agricultural Experiment Station.
- (c) Mr. R. A. Longenbaugh, Junior Civil Engineer and M. W. Bittinger, Associate Civil Engineer.
- (d) Theoretical and field investigation; applied research.
- (e) It is the purpose to study the operating characteristics of ground water reservoirs in Colorado. Specific studies include (1) natural recharge from ephemeral streams, (2) electric analog study of High Plains aquifer, (3) evaluation of natural recharge to High Plains aquifer, and (4) comprehensive analysis of well growth including quantities of water pumped.
- (g) (1) Kiowa Creek data analysis reveals influence of ephemeral stream flow on irrigation wells. (2) Pumped water constitutes large portion of irrigation supply in Arkansas and South Platte River valleys. (3) Mathematical models have shown importance of priority of rights, aquifer characteristics, ground water pumping and consumptive demand on management of an integrated surface-ground water system.
- (4108) WATERSHED HYDROLOGY.
- (b) Colorado Agricultural Experiment Station.

- (c) Dr. V. M. Yevdjovich, Prof. of Civil Engineering.
- (d) Theoretical and experimental; basic research.
- (e) The research is concerned with floods from small watersheds. It is being pursued in three phases: (1) Assembly of research data from actual floods on small watersheds, (2) physical experimental studies on a large rainfall-runoff simulation area, and (3) theoretical studies of the relation between flood hydrographs and the rainfall and catchment factors that affect them.
- (f) Phase one is active, data collection having progressed well; Phase Two is active in the planning stages, and Phase Three is active in the initial stage.
- (h) "The Problem of Integrating Ground Water and Surface Water Use," by Morton W. Eittinger, Oct. 2, 1963.
"Ground and Surface Water Relationships Studied by Statistical Techniques," by Robert A. Longenbaugh and Morton W. Eittinger, Dec. 1963.
"Natural Ground Water Recharge from Kiowa Creek, 1962 Progress Report," by R. A. Longenbaugh, Feb. 1963.
- (4110) TURBULENT AIR MOTION IN THE HIGH ROCKIES IN RELATION TO THE WATER YIELD OF UPPER WATERSHEDS.
- (b) Colorado Agricultural Experiment Station.
- (c) Dr. Herbert Riehl, Professor of Atmospheric Science.
- (d) Field, basic and applied.
- (e) The structure of the turbulent wind eddies, which produce the exchange of momentum between atmosphere and ground in the high mountains, is unknown. Yet these have sufficient force for the most part to blow the snow away from the mountain slopes above timberline. This snow in part drifts into high-altitude basins where it accumulates in depth augmenting the summer water supply; in part it drifts on slopes where it readily evaporates. Much interest has been shown in the possibility of channeling the drift so that a substantially higher fraction goes into the basins. Technologically this appears to be feasible. But any construction is dependent on knowledge of the turbulence spectrum, especially on the first day following snowfall. In order to determine this spectrum, a first installation containing electronic wind and temperature measuring instruments have been established above timberline in the Central Colorado Rockies.
- (f) Field experiments starting in winter of 1963-64.
- (4112) THE DISCHARGE OF MAJOR WESTERN RIVERS IN RELATION TO THE GENERAL CIRCULATION OF THE ATMOSPHERE.
- (b) Office of Naval Research, Department of the Navy.
- (c) Dr. Herbert Riehl, Professor of Atmospheric Science.
- (d) Basic research.
- (e) The discharge of major western rivers (Colorado, Columbia, Sacramento, Rio Grande) has fluctuations with the order of magnitude of the mean annual discharge itself. These fluctuations are brought about mainly by variations in precipitation yield and by variable evaporation. Heavy precipitation may result from seasonal conditions favorable for the recurrence of cyclones over headwater areas. High evaporation, requiring weeks of abnormally dry and warm conditions, must be a manifestation of general circulation anomalies of longer duration. The objective of the study is (1) to separate the "systematic" and "random" components of the precipitation, and (2) to determine the controls for the systematic anomalies of precipitation and evaporation.
- (4114) GRAVEL FILTER FOR TILE DRAINS.
- (b) Colorado Agricultural Experiment Station.
- (c) Mr. Norman A. Evans, Agricultural Engineer.
- (d) Applied; experimental.
- (e) Gravels classed as "pit-run" meeting the criteria for sand filters previously established were used in cylinders simulating mole drains to determine the flow capacity of such drains.
- (f) Completed.
- (g) Tortuosity is a significant geometric property of filter gravels as regards to their permeability.
- (h) "Gravel Fill for Mole Drains," by G. D. Binfield. M.S. Thesis, Colorado State University Library, 1964.
- (4606) STRUCTURE OF TURBULENCE IN TURBULENT SHEAR FLOW.
- (b) Department of the Army.
- (c) Dr. J. E. Cermak, Prof. of Engineering Mechanics and Civil Engineering, Mr. E. J. Plate, Assoc. Professor, and Mr. V. A. Sandborn, Associate Professor.
- (d) Experimental research; basic research, doctoral theses.
- (e) The effects of surface roughness and surface heating or cooling upon the structure of turbulence in boundary layer flow will be determined. The flows investigated will be those existing on the heated or cooled floor of a wind-tunnel test section 6 x 6 ft in cross section and 80 ft long. Space-time correlations, joint probability densities, spectra and intensities of the turbulent velocities and temperatures will be obtained by hot-wire techniques and special analog computers employing magnetic tape input. Efforts are being made to determine the diffusion characteristics for instantaneous point and line sources of heat and mass located within the turbulent boundary layer. This work is another way in which the effect of vertical temperature gradients and the turbulent boundary layer effect the turbulence structure.
- (g) A 2.5 x 10⁻⁵ inch diameter, 90% platinum-10% rhodium wire was evaluated as a resistance thermometer. From steady state evaluation of the wire physical properties the transient response of the wire was predicted. The predictions agree well with measured time constants for the wire. The bare wire with a detection current of 0.1 milliamps will have a sensitivity of approximately .07 millivolts per ° F. The frequency response of the wire in still air is 3200 cycles per second and this increased to approximately 6000 cycles in a moving air stream of 100 feet per second. The recent measurements of spectra within the neutral turbulent boundary layer over the roughened floor of the wind tunnel show very close agreement with turbulent spectra reported for water flow in an ocean tidal channel and for air flow of the sea surface.
- (h) "Local Isotropy in Wind Tunnel Turbulence", by V. A. Sandborn and R. D. Marshall, 1964.
- (4608) TURBULENCE DATA ANALYSIS SYSTEM.
- (b) Department of the Army and National Center for Atmospheric Research.
- (c) V. A. Sandborn, Associate Professor.
- (d) Laboratory development.
- (e) The system employing magnetic tape input is designed to yield the following information: (1) spectra (10⁻³ to 10⁴ cycles/second), (2) joint probability densities, (3) root-mean-squares, and (4) space-time correlation.
- (4611) PERMEABILITY AND CAPILLARY PRESSURE RELATED TO MEDIA PROPERTIES.
- (b) National Science Foundation.
- (c) Dr. A. T. Corey, Prof. of Agricultural Engineering.

- (d) Experimental and theoretical basic research.
 - (e) The study involves an investigation of a tentative theory describing how the functional relationship between relative permeability and relative capillary pressure is related to measurable properties of porous media.
 - (f) Completed.
 - (g) A theory describing the interrelation between capillary pressure, liquid and gas permeability, and liquid saturation has been developed and verified experimentally. The results have been used to develop criteria for similitude in models for studying flow in partially saturated soils.
 - (h) "Hydraulic Properties of Porous Media and Their Relation to Drainage Design," by R. H. Brooks and A. T. Corey, Transactions ASAE, Vol. 7, No. 1, 1964.
 - "Hydraulic Properties of Porous Media," by R. H. Brooks and A. T. Corey, CSU Hydrology Paper No. 3, March 1964.
- (4612) TRANSPORT OF PARTICLES THROUGH UNSATURATED SOILS.
- (b) Department of Health, Education, and Welfare, Bureau of State Service.
 - (c) Dr. A. T. Corey, Prof. of Agricultural Engineering.
 - (d) Applied; experimental.
 - (e) The objective of this research is to determine to what extent the transport of solid particles by water flowing through soil may be affected by the degree of saturation of soil. The term "soil" is interpreted broadly as including sands and gravels as well as agricultural soils. The solid particles to be considered in this study will be of sizes and shapes corresponding to that of viruses.
 - (f) Active, continuing.
 - (g) A considerable amount of data has been accumulated which show that soils (and even sand) have a considerable capacity to adsorb virus-like particles. If, however, a continuous supply of these particles are supplied over a period of time, sand will eventually lose its capacity to retain additional particles. Under the latter conditions virus-like particles may be transmitted for considerable distances through sands (even fine sands).
- (4617) MECHANICS OF LOCAL SCOUR.
- (b) Department of Commerce, Bureau of Public Roads, Hydraulic Research Division.
 - (c) Mr. S. S. Karaki, Associate Professor and Dr. H. W. Shen, Assoc. Professor.
 - (d) Theoretical and experimental; basic research.
 - (e) A theoretical study of the mechanics of local scour is under way to develop basic equations for determining local scour. Basic experiments will be undertaken simultaneously to assist theoretical development.
 - (h) "Mechanics of Local Scour, Part II, Bibliography," S. S. Karaki and Haynie, Annual Report prepared for U. S. Bureau of Public Roads, Civil Engineering Section, Colorado State University, CER63SSk46, Nov. 1963.
- (5161) CHANGE IN QUALITY OF DRAINAGE EFFLUENT FROM IRRIGATION PROJECTS USING A VISCOUS FLOW ANALOGY MODEL.
- (b) U. S. Bureau of Reclamation.
 - (c) Mr. M. W. Bittinger, Assoc. Civil Engineer, Colo. State Univ., Fort Collins, Colo.
 - (d) Experimental.
 - (e) The study is designed to determine quality change (with time) of tile drainage effluent under various aquifer and geometry conditions.
 - (g) Results - Dimensionless curves have been prepared relating quality of effluent to time, permeability, porosity, tile spacing, and distance above impermeable layer,
- and recharge rate for uniform aquifers. Additional studies are being conducted on layered aquifers.
 - (h) "Quality of Effluent from Drains in an Aquifer Containing Saline Water," D. E. L. Maasland and M. W. Bittinger, Civil Engineering Section, Colorado State Univ., CER64DELM-MWB17, May 1964.
- (5164) FLOW MEASUREMENT.
- (b) Colorado Agricultural Experiment Station, Civil Engineering Section and Northern Plains Soil and Water Conservation Research Division, ARS, USDA.
 - (c) Dr. D. B. Simons, Acting Chief, Civil Engineering Research Section, Colo. State Univ., Fort Collins, Colo.
 - (d) Experimental laboratory and basic research which involves staff and graduate student participation leading to M.S. and Ph.D. degrees.
 - (e) This project has the general objective of developing and improving devices and techniques for the measurement of irrigation water. The present activity includes: (1) The further development of the semiconductor strain gage method of measuring velocity in pipes and open channels and its utilization to measure the velocity distribution above and very close to both smooth and rough boundaries in open channels, and (2) continued studies of the trapezoidal measuring flumes, control structures for alluvial channels and other metering devices.
 - (g) A suspension wire probe involving use of semiconductor strain gages has been developed to measure average velocity in pipes and essentially point velocities in open channels. The probe is being further modified to measure velocity very close to boundaries. Also, a pipe insert flow meter is being developed.
 - (h) "A Flume Study of Velocity Distribution with the Suspension Wire Probe," by James Bruce Bole, May 1964.
 - "Pipe Insert Flow Meter," by M. S. Abdallah and D. B. Simons, June 1964.
- (5165) HYDRAULICS.
- (b) Colorado Agricultural Experiment Station and Civil Engineering Section.
 - (c) Dr. D. B. Simons, Acting Chief, Civil Engineering Research Section, Colo. State Univ., Fort Collins, Colo.
 - (d) Basic hydraulic research.
 - (e) This research is in hydraulics oriented toward agriculture and irrigation. The principal areas under study include, fall velocity, sediment transport, resistance to flow in alluvial channels with limited research on rigid boundary hydraulics including loss in bends and the mechanics of flow in alluvial channels.
 - (g) A study has been completed on the fall velocity of gravel size particles. Reports are in preparation on resistance to flow in open channels, bed material transport in open channels, and design of stable channels.
 - (h) "Terminal Fall Velocity of Particles of Irregular shape as Affected by Surface Area," by George R. Alger, July 1964.
 - "Design of Stable Channels in Alluvial Material," by Richard M. Haynie, May 1964.
 - "Sedimentary Structures Generated by Flow in Alluvial Channels," by D. B. Simons, E. V. Richardson and C. P. Nordin, May 1964.
 - "A Study of Variables Affecting Flow Characteristics and Sediment Transport in Alluvial Channels," by D. B. Simons and E. V. Richardson, 1964.
- (5393) MANAGEMENT OF GROUND WATER RESERVOIRS - SURFACE WATER SUPPLIES.
- (b) Colorado Water Conservation Board.

- (c) M. W. Bittinger, Associate Professor.
 - (d) Theoretical and experimental; and applied research.
 - (e) A study of operation and management of ground water reservoirs which are in hydraulic connection with appropriated stream flow. It is the purpose of this study to develop practical conjunctive-use plans so as to alleviate water right conflicts, increase beneficial use and stabilize water supplies for junior appropriators.
 - (g) Systems analysis studies have been completed on simple hypothetical stream-aquifer systems.
 - (h) "The Problem of Integrating Ground Water and Surface Water Use," by Morton W. Bittinger. Issue of Ground Water, Vol. 2, No. 3, July 1964.
"Stream-Aquifer System Analysis for Conjunctive-Use Operations," by Ali Eshett and Morton W. Bittinger. CER64AE-MWB29.
- (5394) ECONOMICS OF WATER TRANSFER: AN INSTITUTIONAL APPRAISAL.
- (b) State of Colorado Experiment Station - Western Regional Project W-81.
 - (c) L. M. Hartman, D. A. Seastone and R. L. Anderson.
 - (d) Theoretical, field investigation, basic research and applied research.
 - (e) The study was set up to investigate and compare various organizations and procedures, which control the use of water in terms of their respective achievement of allocative efficiency. Also, to investigate and estimate demand functions for water in various uses and investigate complimentary and competitive relationships between uses, with emphasis on the implications of these relationships for organizational arrangements.
 - (g) The project has just been initiated and present accomplishments include a rather comprehensive study of the organization of the Northern Colorado Conservancy District.
- (5395) WATERSHED MANAGEMENT PRACTICES AFFECTING WATER SUPPLIES ON IRRIGATION PROJECTS.
- (b) U. S. Bureau of Reclamation.
 - (c) R. E. Dils and J. R. Meiman.
 - (d) Field investigation; applied research.
 - (e) The objectives of this study are: (1) to evaluate the use of dye solutions as a method of determining water yields from watershed subdivisions, (2) to test snow surface additives for the suppression of evaporation and control of snow melt and (3) to study such additional watershed management measures as are suggested by the work and which offer promise of successful application to Bureau projects.
- (5396) EXPERIMENTAL ARTIFICIAL RECHARGE STUDY-ARICKAREE RIVER.
- (b) Colorado Ground Water Commission.
 - (c) Mr. Robert A. Longenbaugh, Instructor.
 - (d) Experimental; applied research and design.
 - (e) The purpose of this study is to determine the feasibility and practicality of artificial ground water recharge with Eastern Colorado ephemeral-stream flood flows using temporary low-cost structures. The project will include the design and evaluation of several different types of recharge structures.
 - (g) Recharge sites have been selected and the design of the low cost spreading structures is now in progress. Construction is planned for January 1, 1965, thus allowing for collection and recharge of spring and summer runoffs. Recharge data is dependent upon runoff flows.
- (5397) PUMPING PLANT EFFICIENCY STUDIES.
- (b) KC, Highline and YW Rural Electric Associations, Kansas-Nebraska and Plateau Natural Gas Companies, and Colorado Farm Power Council.
- (c) Mr. R. A. Longenbaugh, Instructor, Civil Engineering Section, Colorado State Univ., Fort Collins, Colorado.
 - (d) Field investigation and operation.
 - (e) This is a part of an interdepartmental study that is being conducted to determine the pumping costs for the deep well turbine irrigation pumps in Eastern Colorado. Both Natural Gas and Electric pumping plants will be evaluated. Efficiency data will also be used to calculate the total quantity of water pumped from the aquifer.
 - (g) Efficiency data have been collected from 68 deep well turbine pumps and the analysis of pumping costs is underway. For most of the pumping plants it was observed that the pumps were pumping less water and from a greater depth than the farmer expected.
 - (h) Progress report planned for Jan. 1, 1965.
- (5398) ELECTROKINETIC-POTENTIAL-FLUCTUATION METHOD FOR INVESTIGATION OF TURBULENT FLOW.
- (b) National Science Foundation.
 - (c) J. E. Cermak, Professor of Engineering Mechanics in charge of Fluid Mechanics Program, Civil Engineering Section, Foothills Campus, CSU.
 - (d) Experimental and basic research.
 - (e) A systematic study is being made of the response of electrode probes to electrokinetic fluctuations produced by turbulence in flowing water. An effort is being made to determine directional sensitivity of the probes and to optimize their design for use in measuring turbulence characteristics in water. Work in the effect of dissolved salts and different electrode materials on response of the probes is underway.
- (5399) TURBULENT DIFFUSION OF GASES.
- (b) U. S. Army Electronics Material Agency.
 - (c) J. E. Cermak, Prof. of Engrg. Mech. in charge of Fluid Mechanics Program, Civil Engineering Sec., Foothills Campus, CSU.
 - (d) Experimental and basic research.
 - (e) Turbulent diffusion of tracer gas in the turbulent boundary layer is being studied. Two main problems are being studied; (1) turbulent diffusion downstream from a 2-dimensional "hill" and (2) diffusion over and in a simulated vegetated region. In both cases the boundary layer is stratified by either heating or cooling.
- (5400) CHEMICAL SEALING OF WATER CONVEYANCES.
- (b) State of Colorado.
 - (c) Mr. R. D. Dirmeyer, Jr.
 - (d) Experimental and field investigation; applied research and development.
 - (e) The purpose of this project is to develop practical, fast and low-cost design procedures for utilizing chemicals, such as NaCl and Na₂CO₃, for pond sealing purposes. The work is including laboratory evaluations and field trials.
 - (g) A new project initiated July 1963. As of November 1964 1 field trial has been installed. Laboratory evaluations to be completed prior to 5 additional field trials are nearing completion.
- (5401) DIFFUSION IN SHEAR FLOWS.
- (b) Health, Education and Welfare, State Services.
 - (c) Dr. J. E. Cermak, Professor of Engineering Mechanics and In-Charge of Fluid Mechanics Program, and Dr. L. V. Baldwin, Acting Dean, College of Engineering.
 - (d) Experimental; basic research.
 - (e) A study of turbulent diffusion in turbulent boundary layers with varying degrees of thermal stability is being conducted in the micrometeorological wind tunnel. One specific goal is to determine the effect of molecular diffusivity of a diffusing gas upon the overall diffusion rate.

(5402) RESEARCH INITIATION - MEANDERING IN STRAIGHT ALLUVIAL CHANNELS.

- (b) National Science Foundation.
- (c) H. W. Shen, Associate Professor.
- (d) Experimental and theoretical; basic research.
- (e) This is to study the generation of secondary currents between the smooth and rough boundaries in an open channel. The development of secondary currents in the flow is the cause of forming alternating scour holes (commonly known as meander pattern) on the alluvial channel bed.

(5403) SLOT JET INVESTIGATION.

- (b) Kalium Chemical Limited.
- (c) V. M. Yevdjevich, Professor.
- (d) Experimental; basic research.
- (e) The diffusion of submerged circular and two-dimensional jets have been well studied. This investigation refers to slot jet deflection, with various width-length ratio of slots. The time-average velocity distributions, as well as flow rate, momentum and energy changes with distance from the orifice are investigated.
- (g) The distribution of velocities as function of length-width ratio of slot jets have been determined.

(5404) REMOTE SNOW MEASURING DEVICE.

- (b) Jointly with Soil Conservation Service, Forest Service and U. S. Bureau of Reclamation.
- (c) Jack N. Wahichek, Supervisor, USDA and SCS.
- (d) Field investigation; operation and development.
- (e) This device is a 12-foot diameter pillow filled with antifreeze which indicates water content of the snow at the site. This is achieved by the use of a manometer indicating pressure on the pillow. This data can be recorded on standard A-35 or F Recorder or telemetered to any area for reception. Purpose is to develop some instrument to gather continuous data relating to snow pack in the mountainous areas. It will also indicate duration, and intensity of each snow storm. This equipment could be installed in inaccessible areas.

(5405) GROUND WATER IN HIGH PLAINS OF COLORADO.

- (b) Plateau Natural Gas Company.
- (c) M. W. Bittinger, Associate Professor, Civil Engineering Section.
- (d) Thesis.
- (e) A study of ground water management problems and needs in the High Plains of Colorado.
- (f) Completed.
- (g) Natural ground water recharge is negligible to potential development and sound management is needed, based on physical, legal and economic considerations.
- (h) "Some Aspects of Ground Water Development in the Northern Portion of the Colorado High Plains," by E. B. Jones. Ph.D Dissertation, Colorado State University, June 1964.

(5406) EVALUATING STREAM POLLUTION IN THE SOUTH PLATTE RIVER NEAR DENVER, COLORADO USING AERIAL PHOTOGRAPHY.

- (b) Civil Engineering Section, Engineering Research Center, Colorado State University, Ft. Collins, Colorado.
- (c) M. M. Skinner.
- (d) Field investigation and applied research.
- (e) Four film types (black and white, black and white infra-red, color and color infra-red) have been used to photograph a stretch of the South Platte River in the vicinity of Denver, Colorado. The purpose of the study is to (1) Detect the location of outfalls; (2) observe the photographic impression of pollution in the stream; (3) determine film types most suitable for detecting stream

pollution; and (4) develop photo interpretive techniques applicable to stream pollution studies in general.

(5407) WATERSHED ENVIRONMENT AND MICROBIAL DYNAMICS.

- (b) Public Health Service, Water Pollution.
- (c) S. M. Morrison.
- (d) Experimental, basic research.
- (e) A study of the effects of physical and biological environmental factors upon the microbial dynamics of mountain water sources with emphasis upon improved laboratory and field methods. To gain information on the subject of surface water pollution by comprehensive study of the physical, chemical, and biological factors which affect the growth, survival, and distribution of bacterial organisms that are potential enteric pathogens or that are potential indicators of water pollution. Study area in field is the Cache LaPoudre River at elevation 6000/9000 ft. Laboratory studies include refrigerator water-bath simulator of the microbial environment.
- (g) An improved membrane filter--enrichment medium technique developed for detecting enteric bacteria.
- (h) First year report and publications in preparation.

(5408) GEOLOGIC FACTORS CONTRIBUTING TO THE DEVELOPMENT AND HYDROLOGIC CHARACTERISTICS OF MOUNTAIN BOGS AND MEADOWS.

- (b) Rocky Mountain Forest and Range Experiment Station.
- (c) B. C. Goodell.
- (d) Field investigation and thesis.
- (e) The basic objectives of this study are:
 - (1) To map bedrock of study area(s);
 - (2) to log the overlying regolith(s);
 - (3) interpret the information obtained in terms of geologic history and current characteristics of water recharge, storage, and discharge; and (4) to conduct limited tests of these interpretations with tracer techniques.

(5409) PHYSICAL CHARACTERISTICS-SEDIMENT YIELDS, AND STORM HYDROLOGY OF TWO SMALL COLORADO FRONT RANGE WATERSHEDS.

- (b) Colorado Game, Fish, and Parks Dept.
- (c) E. E. Farmer.
- (d) Field investigation and Thesis.
- (e) The major objectives of this study are to: (1) Determine present watershed use and conditions contributing to sediment production and movement and depressed water quality; (2) determine stream bank, channel, and stream discharge conditions contributing to sediment production and movement and depressed water quality; and (3) determine present water quality as related to flow regime. These studies are being conducted on selected tributaries of the North Fork of the Cache LaPoudre watershed.

(5410) WATER UTILIZATION STUDY - ARKANSAS RIVER BASIN-COLORADO.

- (b) State of Colorado.
- (c) M. M. Skinner, Asst. Civil Engineer, Civil Engineering Section Foothills Campus, Colorado State Univ., Fort Collins, Colo.
- (d) Field investigation and applied research.
- (e) A water resource inventory (ground water and surface water) and water utilization study for a 15-county area in South Eastern Colorado. Summary of potential water users to benefit from a new trans-mountain water diversion project and alternate plans for use.

Summary of future water needs. Compilation to be used for planning new developments in the area.

(5411) FACTORS INFLUENCING THE FLOW OF SUBSOIL WATER IN THE IMMEDIATE PROXIMITY OF AND INTO DRAINAGE FACILITIES.

- (b) Colorado Agricultural Experiment Station.
- (c) Dr. A. T. Corey.
- (d) Experimental and theoretical; applied research.
- (e) The work underway in Colorado is for the purpose of perfecting techniques of porous media modeling. When these techniques have been perfected sufficiently a laboratory model of a large field installation will be constructed in the Hydraulics Laboratory. Work to date has established what soil parameters need to be taken into account when a model media is selected. More work needs to be done to determine how to create a satisfactory model medium to satisfy the specific requirements of a model of a particular drainage facility. Work presently underway is intended to accomplish the latter objective.
- (g) If the problems relating to the construction of valid porous media models can be overcome, it will be possible to solve many problems associated with flow into drains that are much too complex for analytical solutions. It is hoped that construction of a laboratory model can begin during the coming year.
- (h) "Hydraulic Properties of Porous Media," R. H. Brooks and A. T. Corey, Colorado State University Hydrology Paper No. 3, March 1964.
"Hydraulic Properties of Porous Media and Their Relation to Drainage Design," by R. H. Brooks, and A. T. Corey. Transactions of the ASAE, Vol. u, No. 1, 1964.

(5412) HYDROMETEOROLOGY OF WESTERN RIVER BASINS.

- (b) Office of Naval Research.
- (c) H. Riehl and J. Rasmussen.
- (d) Experimental; basic research.
- (e) The purpose of this project is to find relationships between the large-scale circulation features of the atmosphere as they affect precipitation over large western watersheds. The study covers daily precipitation and longer period precipitation extending to months and seasons. Computations of daily precipitation minus evaporation from moisture flux computations are being computed with the purpose of obtaining estimates of the evaporation over the basin. The watersheds studied are the Colorado River Basin and the Sacramento River Basin.
- (g) The precipitation regimes of the Colorado river basin have been determined and some circulation features associated with wet and dry periods have been found and the results published in reports listed below.
- (h) "Some Aspects of Colorado River Precipitation, Part I, Precipitation Regimes over the Upper Colorado River," William Marlatt and Herbert Riehl, J. Geoph. Res., 68, 6447-6458, 1963. "Part II. Precipitation Episodes in the Upper Colorado River Basin," Herbert Riehl and R. L. Elsberry, Geofisica pura e Applicata, 57, 213-220, 1964.
"Some Aspects of the Monthly Atmospheric Circulation Affecting Monthly Precipitation over the Colorado River Basin," J. Rasmussen, Technical Paper No. 46, Dec. 1963.

(5413) IMPACT OF LAND USE ON WATER QUALITY WITHIN A FORESTED MOUNTAIN WATERSHED.

- (b) Experiment Station, McIntyre-Stennis.
- (c) James R. Meiman.
- (d) Field investigation; basic research.
- (e) The objectives of this study are to assess present water quality characteristics within a forested mountain watershed

at varying natural flow regimes under land use conditions of limited development to non-use, and to measure the effects of multiple land use management--including road construction, logging, recreational developments, and grazing--on water quality.

CORNELL AERONAUTICAL LABORATORY, INC.

(5193) THEORETICAL STUDY OF HYDROFOIL FLUTTER CHARACTERISTICS.

- (b) David Taylor Model Basin, Office of Naval Research, Dept. of the Navy.
- (c) Dr. Irving C. Statler, Head, Applied Mechanics Dept., Cornell Aeronautical Laboratory, Inc., P. O. Box 235, Buffalo, New York 14221.
- (d) Applied research (theoretical).
- (e) The purpose of this investigation is to formulate the two-degree-of-freedom flutter determinant of a two-dimensional hydrofoil near the free surface and, then, to compute flutter boundaries for various values of system parameters.

(5194) THEORETICAL INVESTIGATION OF FORCES AND MOMENTS ON AN OSCILLATING HYDROFOIL WITH AN OSCILLATING FLAP.

- (b) Bureau of Ships, Dept. of the Navy.
- (c) Dr. Irving C. Statler, Head, Applied Mechanics Dept., Cornell Aeronautical Laboratory, Inc., P. O. Box 235, Buffalo, New York 14221.
- (d) Applied research (theoretical).
- (e) The objective of this study is to compute the lift, total moment and hinge moment for a fully-wetted oscillating hydrofoil with an oscillating flap from the exact, linearized, two-dimensional potential solution. The solution to be used takes full account of the surface waves caused by the hydrofoil.

(5363) UNSTEADY FORCES AND MOMENTS ON A TWO-DIMENSIONAL FULLY CAVITATED HYDROFOIL.

- (b) Bureau of Ships, Dept. of the Navy.
- (c) Dr. Irving C. Statler, Head, Applied Mechanics Dept., Cornell Aeronautical Laboratory, Inc., P. O. Box 235, Buffalo, New York 14221.
- (d) Applied research (theoretical).
- (e) The purpose of the project is to determine the steady and unsteady forces and moments on a fully cavitated hydrofoil operating near a free surface. The approach being taken to this general problem is to use linearized flow theory to examine the forces and moments on a fully cavitating flat plate executing either steady or harmonic motion near a free surface. Full account is taken of the gravity waves generated by the motion of the foil-cavity system and cavitation numbers greater than or equal to zero are considered.

(5364) RADAR INVESTIGATION OF DYNAMICS OF WATER PARTICLE MOTION IN WAVES.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. James W. Ford, Head, Applied Physics Dept., Cornell Aeronautical Laboratory, Inc., P. O. Box 235, Buffalo, N. Y. 14221.
- (d) Applied research (experimental).
- (e) This project is an experimental investigation of the interaction between water waves and electromagnetic radiation in the microwave region. Of particular importance will be to determine the relation between the motion of water waves and the statistical properties of the backscattered microwaves. The results will indicate the usefulness of radar to make remote measurements of velocity characteristics of the sea surface.

CORNELL UNIVERSITY, Department of Agricultural

Engineering.

- (5285) SYNTHESIS OF HYDROGRAPHS AND WATER SURFACE PROFILES FOR UNSTEADY OPEN CHANNEL FLOW WITH LATERAL INFLOWS.
- (b) Ph.D. thesis research, supported by U.S.D.A.-A.R.S.-Soil and Water Conservation Research Division, Cooperative Agreement No. 12-14-100-2433(41).
 - (c) Asst. Prof. R. D. Black, 118 Riley-Robb Hall, Cornell Univ., Ithaca, N. Y. 14850.
 - (d) Experimental and theoretical approach to flood routing for application in streams with significant lateral inflow. This is applied research and a Ph.D. thesis study.
 - (e) This study is a numerical analysis of the complete differential equations for open channel flow. Experimental data for channel roughness and stage discharge relationships were used to route a flood through a reach of channel with lateral inflows added along the length of the routing reach. The numerical solutions were carefully compared with flood wave movements through a 72 foot long experimental channel. The purpose of this work was to develop a method for flood routing in streams where lateral inflow within the routing reach is significant.
 - (f) Completed.
 - (g) The numerical analysis of flood wave movements was in very good agreement with the experimental flood wave movements predicting stages and discharges within 2%. This method should be adaptable in the field if a high speed computer is available to those wishing to use the method. Certain field data necessary for this solution may not be readily attainable but may be deduced from previous hydrographs and in a fashion similar to that used by many present methods.
 - (h) This thesis will be produced as a Cornell University Water Resources paper and will be available by March, 1965, from the Cornell Water Resources Center.
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- CORNELL UNIVERSITY, School of Civil Engineering.
- (4531) SECONDARY CURRENTS IN NON-CIRCULAR CONDUITS.
- (b) National Science Foundation.
 - (c) Dr. J. A. Liggett, Hollister Hall, Cornell Univ., Ithaca, New York.
 - (d) Theoretical and experimental.
 - (e) Those secondary currents caused by Reynold's stresses in straight, non-circular conduits are being studied. A triangular open channel is being used. Measurements are to be taken by the hot-film anemometer.
 - (g) A quantitative theory has been developed and is being tested.
- (5039) PRESSURES DUE TO SUDDEN DRAWDOWN IN EARTH EMBANKMENTS.
- (b) Laboratory project.
 - (c) Dr. J. A. Liggett, Hollister Hall, Cornell Univ., Ithaca, N. Y.
 - (d) Theoretical and experimental; basic and applied research.
 - (e) The equations for unsteady flow in porous media are being solved to find the pressures and free surface shape resulting from sudden drawdown in a porous media. Both analytical and numerical techniques are being used. Experimental work is conducted on a Hele-Shaw model.
 - (h) "Pore-Water Pressures Developed in a Homogeneous Earth Embankment During Sudden Drawdown", J. A. Liggett and M. I. Esrig, Cornell Water Resources Center Report WRC-64-1, 1964.
- (5040) FRICTIONAL EFFECTS IN RIVERS AND WATERWAYS.
- (b) Laboratory project.
 - (c) Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y.
 - (d) Applied research.
 - (e) Under study are different American, English, Indian, Swiss and Austrian rivers and waterways. The data investigated are furnished by the different governmental offices. Report to be published soon.
- (5041) VARIATION OF KARMAN'S K-VALUE IN PIPES CARRYING SUSPENSIONS.
- (b) Laboratory project.
 - (c) Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y.
 - (d) Theoretical.
 - (e) A study of the Karman "K" value, as it appears in the logarithmic velocity distribution equation in an open channel shows considerable variation of its value dependent on the concentration. Under investigation in this research project is a closed pipe with varied concentration of sediment pumped through. Data are already obtained.
- (5302) SETTLING VELOCITIES OF SUSPENDED SOLIDS IN A TURBULENT ENVIRONMENT.
- (b) U. S. Public Health Service.
 - (c) Dr. J. A. Liggett or Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
 - (d) Theoretical and experimental; basic and applied research.
 - (e) The research concerns the effect of turbulence on suspended solids and the rate of settlement of suspended solids.
- (5303) RECESSION HYDROGRAPHS OF IDEALIZED UNCONFINED AQUIFERS.
- (b) Laboratory project.
 - (c) Dr. W. H. Brutsaert, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
 - (d) Experimental and theoretical.
 - (e) A Hele-Shaw model has been constructed to study the different parameters affecting drainage from large unconfined geological formations into stream channels. The obtained ground water recession hydrographs are compared with those derived from previous theoretical, but approximate, solutions. New theoretical analyses are being developed.
- (5304) INVESTIGATIONS ON TWO-PHASE FLOW PROBLEMS.
- (b) College of Engineering, Cornell University.
 - (c) Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
 - (d) Experimental and theoretical research.
 - (e) Various problems encountered in solid-liquid mixture transport are under investigation. Measuring devices for water solid mixtures will be developed.
- (5305) THE PHYSICAL PHENOMENA INVOLVED IN PAN EVAPORATION.
- (b) Laboratory project.
 - (c) Dr. W. H. Brutsaert, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
 - (d) Theoretical and experimental.
 - (e) Evaporation is being measured from a number of insulated shallow pans of different sizes and colors. These experimental results and simultaneous climatological data will be used to check and extend some theoretical models of the hydrodynamics--and also of the energy budget aspects of pan evaporation and evaporation in general.
- (5306) THE HYDRAULICS OF POROUS MEDIA.
- (b) Laboratory project.
 - (c) Dr. W. H. Brutsaert, Hollister Hall, Cornell University, Ithaca, N. Y. 14850.
 - (d) Theoretical and experimental.
 - (e) An analysis is being made of moisture characteristic curves of porous media to describe the pore size distribution by mathematical equations. These distributions are used to calculate hydraulic properties of the media.

- (h) "On Pore Size Distribution and Relative Permeabilities of Porous Mediums," Wilfried Brutsaert, Jour. Geoph. Res., Vol. 68, No. 8, pp 2233-2235, 1963.

(5307) MECHANICS OF INFILTRATION.

- (b) Laboratory project.
- (c) Dr. W. H. Brutsaert, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
- (d) Theoretical.
- (e) The micro hydrological equations of unsaturated flow in porous media are being investigated and solved for different boundary conditions. The results of the mathematical analysis are extended to develop infiltration equations for larger areas or for an entire watershed.

(5308) END-DEPTH STUDIES IN CHANNELS WITH MILD SLOPE.

- (b) Laboratory project.
- (c) Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
- (d) Applied research.
- (e) The ultimate scope is to find end-depth relationship for channels with different geometrics.

UNIVERSITY OF DELAWARE, Fluid Mechanics Laboratory Section, Dept. of Civil Engineering.

(4123) STUDIES ON MECHANICS OF FLUID FLOW.

- (b) Laboratory and U.D.R.F. project.
- (c) Department of Civil Engineering, Dr. K. P. H. Frey, Professor, Univ. of Delaware, Newark, Del. 19711.
- (d) Experimental; basic, applied research; educational aid.
- (e) New tests to verify the method of flow control by cusps designs based on potential vortex motion theory: (a) The recent review of the theory considered stability criteria for flow control and suggested specific shapes for two dimensional models. Our objective was to test such models in water and air flow at a large range of velocities. The cusps were 16 and 32 inches wide (span) and 3 and 6 inches deep. Studies in water comprised free surface flow as well as fully submerged objects with and without end plates. (b) In addition, a three dimensional plexiglass cusp diffuser model has been constructed for extension of previous tests: inlet diameter is 6 inches, enlarged section is 12 inches diameter; the model approximately 10 ft. long is under study in water and air flow.
- (g) None of the tests verified the applicability of the known theory for flow control in water and air flow. Test results encourage further studies of the phenomena.
- (h) Previous progress report presented as paper: "Tests on Flow Development in Diffusers," K. P. H. Frey and N. C. Vasuki, Symposium on Fully Separated Flows, pp. 40 to 47, ASME Fluids Engineering Division Conference, Philadelphia, Pa., May 18-20, 1964. Unpublished results of the new tests (stimulated by the paper "Discussion of Problems Associated With Standing Vortices and Their Applications", F. O. Ringleb, same reference, pp. 33-39) have been shown at that conference by K. P. H. Frey and N. C. Vasuki.

(5049) TURBULENT FLOW OF NON-NEWTONIAN SUSPENSIONS.

- (b) UDRF project.
- (c) Dept. of Civil Engineering, Dr. Iraj Zandi, Asst. Professor, Univ. of Delaware, Newark, Del. 19711.
- (d) Analytical and experimental.
- (e) Development of analytical technique for prediction of head loss in a closed conduit

due to transport of suspension. The study is based on the boundary-layer theory in a turbulent flow with the consideration of the fact that the flow becomes non-Newtonian as the concentration of the solid in suspension increases. The equation will predict head losses in a pipe from only basic rheological properties of the fluid.

- (g) The differential equations of motion for laminar, buffer and turbulent zones are developed for flow of non-Newtonian suspensions in pipes. Velocity profile data for non-Newtonian fluids which behave according to the power model are taken from literature and compared with the model developed (with the aid of the computer). Excellent results are obtained for the turbulent and laminar regions. More study is needed to establish the validity of the model in the case of buffer zone.

(5050) URBAN HYDROLOGIC STUDY.

- (b) Laboratory project and partly Storm Drainage Project of The Johns Hopkins University.
- (c) Dept. of Civil Engineering, Dr. Iraj Zandi, Asst. Professor, Univ. of Delaware, Newark, Del. 19711.
- (d) Applied research.
- (e) Hydrologic study of the effect of urbanization upon relationship between rainfall and runoff. Two completely defined areas are gaged and precipitation and runoff is continuously recorded. These two areas consist of two adjacent sections of East Cleveland Avenue in Newark, Delaware. Rainfall measurements are obtained by the use of two tipping bucket rain gages, one being installed on each area. East Cleveland Avenue is a bituminous paved street 44 feet wide having concrete curb as gutter sections. The physical characteristics of areas are indicated below:

- Area (1) 0.636 Acres; 100% impervious; with average slope of 3.35%.
- Area (2) .955 acres; 100% impervious; with average slope of 0.58%.

The runoff is measured by a 9-and a 12-inch parshall flume.

- (g) Collection of data is continued during 1964 season and a partial analysis of data is undertaken.
- (5365) SLIP VELOCITY IN TWO-PHASE FLOW (SOLID-LIQUID).
- (b) Laboratory project.
- (c) Dept of Civil Engineering, Dr. Iraj Zandi, Asst. Prof., Univ. of Delaware, Newark, Del. 19711.
- (d) Analytical and experimental research for M.S. thesis.
- (e) In study of suspension flow in pipes a major factor to be considered is slip velocity (difference of velocity between solid particles and fluid). There seems to be a direct relationship between slip velocity and differential head loss (difference of head loss between suspension flow and clear water flow for the same mean velocity). The purpose of this study is to determine the slip velocity.
- (g) The experimental set up is completed and is ready for test. A reference book on diverse flow phenomena comprising approximately 240 flow pattern photographs is expected to be completed in 1965 by K. P. H. Frey in collaboration with N. C. Vasuki. Most recent results will be included in this work.

(5366) OPEN LOOP WIND TUNNEL.

- (b) Laboratory project.
- (c) Dept. of Civil Engineering, Dr. K. P. H. Frey, Univ. of Delaware, Newark, Del. 19711.
- (d) Design, operation, development.
- (e) The previous closed loop wind tunnel (10 H.P, test section 18 x 18 x 48 inches) is now

operated with an open loop. Test section 12 ft. long. Nozzle contraction ratio increased from 2 to 10.8. Purpose: improvement at low costs.

- (f) Active, completed for certain operations in November 1964.
- (g) Reduced turbulence, vibrations, heat generation; increased velocity; greater flexibility of work.

UNIVERSITY OF DELAWARE, Department of Mechanical Engrg.

(4556) DRAG REDUCTION BY BOUNDARY LAYER GAS INJECTION, (INCLUDING STABILITY CONSIDERATIONS).

- (b) Laboratory project.
- (c) Prof. B. Seidel, Prof. J. P. Harnett, Prof. K. Frey, (Civil Engineering) Univ. of Delaware, Newark, Delaware.
- (d) Theoretical and experimental; master's and doctoral thesis.
- (e) The possibility of reducing the skin-friction drag of a body moving through a liquid by ejecting air from the body is being investigated. Measurements of the drag on a flat plate are being obtained. The stability of the gas film is being analyzed.

UNIVERSITY OF FLORIDA, The Engineering and Industrial Experiment Station, Coastal Engineering Laboratory.

Inquiries concerning projects should be addressed to Dr. Per Bruun, Head, Coastal Engineering Laboratory, University of Florida, Gainesville, Florida.

(3413) INLET STUDIES.

- (b) Laboratory project.
- (d) Field investigation; applied research.
- (e) Study of the stability of coastal inlets.

(4127) FLUORESCENT TRACING OF SEDIMENT IN COASTAL AREAS.

- (b) National Institute of Health, Department of Health, Education and Welfare.
- (d) Field investigation; basic and applied research.
- (e) Tracing of sediment drift on beach and off-shore bottoms by means of injected fluorescent material.
- (g) Statistical sampling methods, rapid measurement fluorescent tracer concentration by electronic scanners, a new longshore current theory and a statistical approach to littoral transport mechanism are being developed at the laboratory.
- (h) "Quantitative Tracing of Littoral Drift," paper presented at the IXth International Conference on Coastal Engineering, Lisbon 1964.

(4128) FLUX OF WAVE ENERGY PERPENDICULAR TO THE DIRECTION OF WAVE PROPAGATION.

- (b) National Science Foundation.
- (d) Basic research.
- (e) Experiments to determine flux of wave energy perpendicular to the direction of wave propagation.
- (f) Discontinued.
- (h) Report submitted to National Science Foundation.

(4129) INFLUENCE OF SEA LEVEL RISE ON EROSION.

- (b) State Government.
- (d) Basic field research.
- (e) To determine the influence of short-term as well as long-term fluctuation of sea level on erosion and shoreline movements.
- (g) Tracer experiment being undertaken on transversal drift.

(4474) COASTAL ENGINEERING STUDY AT SOUTH LAKE WORTH INLET, FLORIDA.

- (b) South Lake Worth Inlet District Commission.
- (c) South Lake Worth Inlet District Commission, c/o K. C. Mock and Associates, 2930 Okeechobee Road, West Palm Beach, Florida.
- (d) Experimental field and applied research.
- (e) To study distribution of inlet currents, improvement of entrance jetties, and navigation channels and measures against beach erosion. Also study the effect of proposed landfills in the bay.
- (f) Completed.
- (h) Report submitted to sponsor.

(4475) COASTAL ENGINEERING STUDY AT HILLSBORO INLET, FLORIDA.

- (b) Hillsboro Inlet Improvement and Maintenance District, City of Pompano Beach and Trustees of the Internal Improvement Fund.
- (c) Director, Trustees, Internal Improvement Fund, Capitol Bldg., Tallahassee, Florida.
- (d) Experimental, field and applied research.
- (e) To study methods for inlet stabilization, navigation improvement, and sand bypassing across the inlet.

(4477) COOPERATIVE STUDY OF SHORE PROTECTION STRUCTURES IN FLORIDA (in cooperation with U. S. Army Corps of Engineers, Jacksonville District).

- (b) State and Federal Government.
- (d) Field investigation; applied research.
- (e) To study effectiveness and structural durability of various types of shore protection structures existing along Florida coastline by making repetitive surveys of selected shore segments.
- (f) Suspended.

(4479) REVIEW OF BEACH EROSION AND STORM TIDE SITUATION IN FLORIDA.

- (b) Engineering and Industrial Experiment Sta., University of Florida.
- (d) Field investigation; applied research.
- (e) Photographic review of the erosion situation in Florida and preliminary suggestions for remedial measures.
- (f) Research continued.

(4481) INVESTIGATION OF STABILITY AND MOVABLE BED MODEL LAWS OF INLETS.

- (b) Laboratory project.
- (d) Basic and applied research.
- (e) With a new basic approach to similitude laws in sediment transport by currents, investigations are underway in the stability analysis of inlets by means of model studies of suitable inlets. A theoretical study of model laws for movable bed models initiated as introductory to inlet study.
- (h) "Similarity of Bed Load Transport by Currents," by J. A. Battjes, under preparation.

(4482) EXPERIMENTAL STUDY OF MECHANICS OF DUNE BUILDING AT CAPE HATTERAS NATIONAL SEASHORE AREA.

- (b) Cape Hatteras National Seashore, National Park Service, Manteo, North Carolina.
- (c) Cape Hatteras National Seashore, National Parks Service, Manteo, North Carolina.
- (d) Experimental and field research.
- (e) Study of mechanics of dune building by various types of sand fences and other sand catchment devices under controlled conditions is underway in a laboratory wind tunnel to be later correlated with field tests.

(4895) SAND TRANSPORT BY WIND & MECHANICS OF DUNE BUILDING.

- (b) National Science Foundation, Washington, D.C.
- (d) Experimental and theoretical; basic research.
- (e) To study the basic mechanics of sand transport by wind under dry and humid conditions, with and without vegetation, uniform and gusty winds and with and without solid and permeable vertical fences.

- (4896) HYDRAULIC MODEL TESTS FOR SUCTION WELL DESIGN FOR MIAMI RIVER WELL TREATMENT PLANT, DAYTON, OHIO.
- (b) F.M.C. Corporation, Hydrodynamic Division, Peerless Pump, Indianapolis, Indiana.
 - (d) Experimental & applied research.
 - (e) To determine the most optimum compatible location and design of suction well baffling for the field treatment plant.
 - (f) Completed.
 - (h) Report submitted to sponsor.
- (4897) COASTAL ENGINEERING STUDY OF SEBASTIAN INLET, FLORIDA.
- (b) Sebastian Inlet, District, Melbourne, Florida.
 - (d) Experimental and applied research.
 - (e) To conduct field survey and model study of the inlet for least shore erosion and best navigable inlet conditions.
- (4898) BASIC RESEARCH ON LITTORAL DRIFT BY WAVE AND CURRENT ACTION.
- (b) National Science Foundation, Wash., D. C.
 - (d) Experimental and basic research.
 - (e) A laboratory basic research project on friction coefficients and sediment transport by currents and waves running with or against each other and running perpendicular to each other.
- (4899) HYDRAULIC MODEL STUDY OF BURNS WATERWAY HARBOR, INDIANA.
- (b) Indiana Port Commission, State of Indiana, Indianapolis, Indiana.
 - (d) Experimental and applied research.
 - (e) Laboratory model study of the effects of diffraction, siltation, and harbor surging on the proposed harbor.
- (5281) TRACING OF LITTORAL DRIFT AT CAPE KENNEDY.
- (b) Field project.
 - (c) Atomic Energy Commission.
 - (d) Basic applied research.
 - (e) Special tracer project on transversal drift in bottom and beach profile.
- (5282) PROTECTION FOR DREDGE OPERATION IN NEW YORK BAY.
- (b) Laboratory project.
 - (c) Gahagan Dredging Co., Pacific, Atlantic, and Gulf Dredging Co.
 - (d) Applied.
 - (e) To arrange proper protection for dredging operation at Staten Island, N. Y.
- (5283) SCRAPER OPERATION, JUPITER ISLAND.
- (b) Field project.
 - (c) Coastal Engineering Research Center and Coastal Engineering Laboratory Cooperative project.
 - (d) Applied and basic.
 - (e) To check on operation of offshore scraper dragging sand in from 800 ft. from shore at 12-15 ft. depth.
- (5284) SAND FENCES.
- (b) Laboratory project.
 - (c) Coastal Engineering Research Center, Wash., D. C.
 - (d) Applied.
 - (e) To test various sand fences.
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- GEORGIA INSTITUTE OF TECHNOLOGY, Engineering Experiment Station.
- (3725) SECONDARY MOTION IN ENCLOSED CONDUITS AND OPEN CHANNELS.
- (b) Laboratory project.
- (c) Dr. P. G. Mayer, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.
- (d) Theoretical and experimental; research for Ph.D. thesis.
- (e) A fundamental study of secondary motion in turbulent flows. Secondary motions are often superimposed upon flows in enclosed conduits and open channels. The mode of origin, development and decay is being studied to delineate the influence on the general motion pattern in straight, non-circular conduits and channels. The present phase concerns turbulent flow in a non-circular enclosed conduit.
- (f) Completed.
- (h) "Turbulent Flow in a Three-Dimensional Channel," Ph.D thesis, H. J. Tracy, Oct. 1963.
- (4574) THE ROLE OF A PERMEABLE BED IN SEDIMENT TRANSPORT.
- (b) Laboratory project; partly sponsored by Bureau of Ships, Department of the Navy.
 - (c) Dr. C. S. Martin, School of Civil Engineering, Georgia Inst. of Tech., Atlanta, Georgia 30332.
 - (d) Analytical and theoretical; fundamental research.
 - (e) The effect of a permeable bed on incipient sediment motion is investigated for oscillatory waves over a porous sea bed and for seepage out of an unlined canal. Conclusions are reached as regards the effect of the seepage on the flow characteristics in the vicinity of the bed as well as the magnitude of the seepage force and its effect on incipient motion.
 - (f) Completed.
 - (g) It was found that the effect of a permeable bed on incipient motion is not usually significant inasmuch as the seepage force is essentially offset by the altering of the boundary shear stress by the seepage. A thorough discussion is presented.
 - (h) "The Role of a Permeable Bed in Incipient Sediment Motion," C. S. Martin, Ph.D thesis, 150 pages, June 1964.
- (4576) FLOW CHARACTERISTICS OF A TWO-DIMENSIONAL ORIFICE PLACED UNSYMMETRICALLY IN THE APPROACH CHANNEL.
- (b) Laboratory project at Georgia Institute of Technology and at SEATO Graduate School of Engineering, Bangkok, Thailand.
 - (c) Dr. M. R. Carstens, School of Civil Engineering, Ga. Inst. of Tech., Atlanta, Georgia 30332.
 - (d) Experimental and theoretical; research for M.S. theses.
 - (e) The flow characteristics, coefficient of contraction and angle of jet deflection, were to be determined both analytically and theoretically.
 - (f) Continuing.
 - (g) Experimental results have been obtained for opening width-approach channel width ratios of 0.2, 0.4, 0.6, and 0.8, for a range of opening eccentricities. Theoretical results have been evaluated for symmetrical jet and for maximum eccentricity. Numerical integration is being done for intermediate eccentricities.
- (4579) WHIRLPOOL FORMATION AND VORTEX STRETCHING.
- (b) Laboratory project; partly sponsored by the Georgia Power Company, Atlanta, Georgia.
 - (c) Dr. P. G. Mayer, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.
 - (d) Experimental and theoretical.
 - (e) Asymmetric approach condition to the suction bells of centrifugal pumps led to severe whirlpool formation, prerotation, and air entrainment. A model study was conducted to alleviate existing conditions in a condenser-water circulating system. A rotating

- pot apparatus was built subsequently to study free vortex motion and vortex stretching under controlled conditions.
- (f) Suspended; Dr. Mayer is in England on leave of absence.
- (g) Laboratory measurements and photographic analysis of vortices permitted a comparison with results predicted by hydrodynamic relationships.
- (4580) ISOTROPIC-TURBULENCE WATER TUNNEL.
- (b) Laboratory project; sponsored partly by U. S. Geological Survey.
- (c) Dr. P. G. Mayer, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.
- (d) Experimental and theoretical.
- (e) In order to establish response characteristics of turbulence probes, a known field of turbulence is necessary. Isotropic turbulence can be created behind square-mesh grids and results of the decay of isotropic turbulence have been known from wind tunnel studies. The experimental flow system consists of a head tank, a contraction cone, an 8-inch diameter test section and a tail-water bay. The turbulence-generating grid was built into the throat of the contraction cone.
- (f) Suspended; Dr. Mayer is in England on leave of absence.
- (4581) INFLUENCE OF ROUGHNESSES ON FLOW ESTABLISHMENT AND VELOCITY DISTRIBUTION IN OPEN CHANNEL FLOW.
- (b) Laboratory project; partly sponsored by U. S. Geological Survey.
- (c) Dr. P. G. Mayer, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.
- (d) Experimental; research for M. S. thesis.
- (e) Vorticity and secondary motions are created at channel transitions. The longevity of these vortices is to be investigated in a 80-foot-long variable-slope channel. The velocity profiles of the developing flows are to be compared with one another for various channel conditions. The deformation and recovery of velocity profiles downstream from disturbances are to be investigated.
- (f) Suspended; Dr. Mayer is in England on leave of absence.
- (4582) INVESTIGATION OF THE ENERGY SPECTRUM OF TURBULENCE IN A CLOSED RECTANGULAR CONDUIT.
- (b) Laboratory project.
- (c) Dr. G. M. Slaughter, School of Civil Engrg., Georgia Institute of Technology, Atlanta, Georgia 30332.
- (d) Experimental; basic research for doctoral dissertation.
- (e) Energy spectra are being investigated in a wind tunnel study. A hot wire anemometer and a wave analyzer are being used to measure spectral components in the stream-wise direction. Various physical changes at the entrance to the wind tunnel create different turbulence conditions in order to shed light on the mechanism of turbulence-energy transfer.
- (f) Completed.
- (g) It was found that for each spectrum investigated, a wave number exists beyond which the spectrum is universal in shape and character. Conversely, the shape and character of the spectrum in the low-wave-number range is very much dependent upon the manner in which the turbulence is produced or generated.
- (h) "Investigation of the Energy Spectrum of Turbulence in a Closed Rectangular Conduit," George M. Slaughter, Ph.D thesis, 170 pp, 1965.
- (4584) VISCOUS FLUID FLOW UNDER THE INFLUENCE OF A RESONANT ACOUSTIC FIELD.
- (b) Aerospace Research Laboratories, Office of Aerospace Research, United States Air Force.
- (c) Prof. T. W. Jackson, School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.
- (d) Experimental and theoretical; research for master's and doctor's theses.
- (e) An experimental and theoretical study of the effects of resonant acoustic vibrations on the fluid flow and heat transfer in a 4-inch horizontal tube heated by steam. Air was used as the fluid, resonant frequencies were 220 and 356 cps, and sound pressure levels up to 164 decibels were obtained.
- (g) The existence of standing vortices in the tube were confirmed experimentally by a visualization study of the flow. Periodic variations in the heat transfer coefficient were obtained and the period of the variation is a half wave-length of the resonant frequency. The resonant vibrations tended to increase the overall heat transfer for laminar flow and decrease it for turbulent flow conditions. Analytical solutions for the channel and tube configurations have been obtained for the momentum and continuity equations.
- (h) "Viscous Fluid Flow Under the Influence of a Resonant Acoustic Field," Ph.D thesis, School of Mechanical Engineering, K. R. Purdy, 1963. "Laminar Forced Convection Under the Influence of a Resonant Acoustic Field," Ph.D thesis, School of Mechanical Engineering, H. G. Keith, 1965.
- (4585) THE VISCOSITY OF HIGH PRESSURE STEAM.
- (b) National Science Foundation.
- (c) Prof. T. W. Jackson, School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.
- (d) Experimental and theoretical; research for master's and doctor's theses.
- (e) An experimental and theoretical study of the viscosity of steam to 10,000 psi and 1200 degrees F.
- (g) Experimental data have been obtained for the viscosity of steam using an annulus type transpiration viscosimeter. A unique method of measuring small pressure drops at very high static pressures was developed. Experimental and theoretical work are continuing on the project.
- (h) "A Comparison of the Available Viscosity Data of High Pressure and High Temperature Steam with a Modified Reinganum's Equation for Viscosity," M.S. thesis, School of Mechanical Engineering, H. H. Y. Yen, 1964. "The Viscosity of Steam to 10,000 psia," Thermophysical Prop. Sym., Purdue Univ., March 1965, T. W. Jackson, B. Latto, C. E. Willbanks, J. Hodgson, and H. H. Y. Yen.
- (4586) MASS TRANSFER IN THE ENTRANCE LENGTH OF A PIPE - LAMINAR FLOW.
- (b) Departmental research.
- (c) Prof. H. C. Ward, School of Chemical Engrg., Georgia Institute of Technology, Atlanta, Georgia 30332.
- (d) Experimental and theoretical; basic research for doctor's thesis.
- (e) Flow conditions are being extended and unusual natural convection effects are being investigated.
- (4589) VARIABLE PROPERTY HEAT TRANSFER IN THE ENTRANCE OF A TUBE.
- (b) Departmental research.
- (c) Prof. H. C. Ward, School of Chemical Engrg., Georgia Inst. of Tech., Atlanta, Georgia 30332.
- (d) Theoretical; basic research for doctor's thesis.
- (e) Numerical solutions for the momentum, energy, and continuity equations are being developed for a variable property fluid flowing laminarily in the entrance of a vertical tube.

- (5027) CHEMICAL ASPECTS OF SAND FILTRATION.
- (b) U. S. Public Health Service.
 - (c) Dr. C. R. O'Melia, School of Civil Engrg., Georgia Inst. of Tech., Atlanta, Ga. 30332.
 - (d) Experimental and theoretical; applied research for master's thesis.
 - (e) A study designed to demonstrate chemical effects in the removal of flocculent materials from aqueous suspension and filtration and to investigate the causes of these effects.
 - (f) Continuing.
- (5028) EFFICACY OF A FRESH-WATER CANAL FOR THE ALLEVIATION OF THE EFFECTS OF SALT-WATER INTRUSION AT A DELTA.
- (b) Laboratory project.
 - (c) Dr. M. R. Carstens, School of Civil Engrg., Georgia Inst. of Tech., Atlanta, Ga. 30332.
 - (d) Theoretical; research for doctoral thesis.
 - (e) Solutions are being obtained for seepage flow out of a fresh-water canal located at the junction of delta and the sea. Particular interest is centered upon the lowering of the salt-water, fresh-water interface in the delta. Numerical solutions are being obtained for various canal locations, water levels in the canal, and drain locations.
 - (f) Completed.
 - (h) "Effectiveness of an Artificial Fresh-Water Barrier in the Alleviation of the Effects of Salt-Water Intrusion," S. Charmonman, Ph.D thesis, 161 pp., June 1964.
- (5029) UNSTEADY FLOW IN A PIPE.
- (b) National Science Foundation.
 - (c) Dr. M. R. Carstens, School of Civil Engrg., Georgia Inst. of Tech., Atlanta, Ga. 30332.
 - (d) Experimental; design and development of equipment and basic research for master's thesis.
 - (e) A device for the study of unsteady flow in a pipe has been designed, fabricated, and tested. Liquid is moved harmonically in the test pipe. Velocity and acceleration are independent variables with the measured pressure gradient being dependent. The basic research is primarily directed to the determination of boundary-shear stress for turbulent flow in a smooth pipe.
 - (f) Completed.
 - (h) Report available upon request.
- (5151) MULTICOMPONENT CONDENSATION IN THE ENTRANCE LENGTH OF A VERTICAL TUBE.
- (b) Departmental research.
 - (c) Prof. H. C. Ward, School of Chemical Engrg., Georgia Inst. of Tech., Atlanta, Ga. 30332.
 - (d) Theoretical, basic research for doctor's thesis.
 - (e) The boundary layer equations are being used to describe the liquid and gas phases in the entrance length of a vertical tube to determine possible effects of the entrance length on condensation. Fractionation is being considered.
- (5367) MASS TRANSFER AND/OR CHEMICAL REACTION IN POWER LAW NON-NEWTONIAN FLUIDS.
- (b) Departmental project.
 - (c) Prof. H. C. Ward, School of Chemical Engrg., Georgia Inst. of Tech., Atlanta, Ga. 30332.
 - (d) Theoretical; basic research for doctor's thesis.
 - (e) Numerical solutions are being developed for the continuity, momentum, diffusion and energy equations for a variable property power law fluid reacting and/or diffusing in laminar flow in a vertical tube. The constant property entrance problem is also considered.
- (5545) AN ANALYTICAL AND EXPERIMENTAL STUDY OF BED RIPPLES UNDER WATER WAVES.
- (b) Corps of Engineers, U. S. Army, Coastal Engineering Research Center, 5201 Little Falls Road, N. W., Washington, D. C. 20016.
 - (c) Dr. M. R. Carstens, School of Civil Engrg., Georgia Institute of Technology, Atlanta, Georgia 30332.
 - (d) Experimental and theoretical; basic research for sponsor.
 - (e) Experimental measurements of rate of ripple propagation, ripple geometry, and energy dissipation of bed ripples generated over a plane erodible bed. Experiments are being conducted in the Georgia Tech U-tube water tunnel in which water is oscillated with simple-harmonic motion over a stationary sediment bed. Independent variables are amplitude of water motion, frequency of oscillation, size of disturbance element from which the ripples originate, and characteristics of the bed material. Results are to be compared with theoretical model.
 - (h) Quarterly progress reports.
- (5546) CROSS-CHANNEL DIFFUSION.
- (b) Laboratory project.
 - (c) Dr. M. R. Carstens, School of Civil Engrg., Georgia Institute of Technology, Atlanta, Georgia 30332.
 - (d) Theoretical and experimental, research for Ph.D thesis.
 - (e) A study of shear flows as characterized by lateral transfer of linear momentum. This lateral transport of linear momentum can be accomplished by molecular diffusion, by turbulent diffusion, or by secondary currents superposed on the mean flow. In open channel flow, the existence of all modes of linear momentum transfer is likely especially if the stream section consists of a main channel section and an overbank section. In this study air is being used in conjunction with an enclosed conduit consisting of a rectangular main channel with rectangular overbank section projecting from the center of one wall of the main channel. Geometric variations will be confined to this overall shape. Flow analyses are being made using detailed velocity measurements throughout a cross-section, Preston-tube measurements along the wall of a cross-section, and piezometric head measurements along the axis of the conduit. In this initial study direct measurement of turbulence characteristics will not be attempted. Instead linear-momentum transport will be computed from the mean-flow measurements listed above.
 - (f) Analytical and experimental work now in progress.
 - (g) Velocity profiles and boundary-shear distribution have been determined for one channel section.
- (5547) SEDIMENT TRANSPORT FUNCTIONS WITH SPECIAL EMPHASIS ON LOCALIZED SCOUR.
- (b) Laboratory project.
 - (c) Dr. M. R. Carstens, School of Civil Engrg., Georgia Institute of Technology, Atlanta, Georgia 30332.
 - (d) Experimental; basic research for doctoral dissertation.
 - (e) Experimental measurement of rate of sediment transport from an idealized scour hole and from a plane bed. Steady state conditions were obtained by feeding sediment to the scour area at a known rate. 100 to 1 variation in supply rate. Sediment specific weight varied from 1.18 to 8.75. Diameters from 0.111 mm to 0.57 mm.

UNIVERSITY OF IDAHO, Engineering Experiment Station.

Inquiries concerning Projects Nos. 1859, 3056, 3057, 3416, 5167 and 5168 should be addressed to Prof. C. C. Warnick, College of Engineering, and for Projects Nos. 1862 and 2786, should be addressed

to Prof. G. L. Corey, Dept. of Agricultural Engrg., Univ. of Idaho, Moscow, Idaho 83843.

(1859) INVESTIGATION OF METHODS OF CONTROLLING AND EVALUATING CANAL SEEPAGE.

- (b) Laboratory project; in cooperation with U. S. Bureau of Reclamation.
- (d) Experimental and field investigation; basic and operational with master's thesis.
- (e) Different types of canal linings are being studied and various ways of evaluating performance are being considered, especially ideas for measuring canal seepage from both lined and unlined canals.
- (g) New sealants are being investigated in experimental sections of irrigation canals. Techniques for measuring seepage are being compared in simultaneous testing in by-pass sections of canal.
- (h) "Determination of Hydraulic Conductivity Using Piezometer Tubes", J. A. Ross, M. S. Thesis, Univ. of Idaho, 1964.

(1862) DETERMINATION OF ANNUAL RUNOFF FROM WATERSHED CHARACTERISTICS.

- (b) Laboratory project; being carried on under Agricultural Experiment Station.
- (d) Experimental; applied research.
- (e) A study of the hydrological factors affecting the Moscow Mountain Watershed as it applied to the total water use in the area.
- (g) Measurement data on a small watershed is continuing to be collected.

(2786) FARM IRRIGATION EFFICIENCIES.

- (b) Laboratory project; cooperative with the Bureau of Reclamation under the Agricultural Experiment Station.
- (d) Field investigation; basic and applied research.
- (e) To evaluate irrigation efficiencies on actual farms to aid in planning of a water use on irrigation projects. To consider efficiency from aspect of farm operations and not just consumptive use of crops.
- (f) Completed.
- (g) Basic field data have been collected for five years. Final results are being prepared for publication.
- (h) "Water Use Evaluation on New Irrigation Projects", C. L. Tyler, G. L. Corey and L. R. Swarner. Univ. of Idaho, Agr. Exp. Station Research Bulletin 62.

(3056) TELEMETERING HYDROLOGIC DATA FROM MOUNTAIN LOCATIONS.

- (b) Laboratory project; in cooperation with Federal agencies and power companies.
- (d) Laboratory and field investigation; basic and applied operational research.
- (e) A complete system for reporting six or more hydrologic data is being studied and basic parameters of snow melt are being studied for conversion into time delay circuits for transmission by radio.
- (g) Prototype unit is being tested on Moscow Mountain; elements of measurement transducers are being studied both in the field and in the laboratory. License for station has been approved.
- (h) "Telemetering Hydrologic Data from Mountain Locations", E. E. Gray, K. E. Waltz, J. D. Logan, D. L. Duncan and J. M. Shearer. Univ. of Idaho, Engr. Exp. Station. Summary and Progress Report No. 6.

(3057) CONSERVATION OF WATER FOR RANGE STOCK.

- (b) Laboratory project; in cooperation with Bureau of Land Management and ranchers.
- (d) Field investigation; applied operational research.
- (e) Experimental stock watering ponds in desert areas will be lined and evaporation control measures supplied to see if extension of such water supply can be developed economically.

- (g) Several ponds lined and unlined are being studied and enonomolecular films are being experimented with to find net water savings. The hydrology of small ponds is also being investigated.

- (h) Progress report to be issued early in 1965.

(3416) STUDY OF METHODS FOR AUTOMATIC MEASUREMENT OF SNOW WATER CONTENT.

- (b) Laboratory project; cooperative with Agricultural Research Service, U. S. Dept. of Agriculture.
- (d) Field investigation; applied research.
- (e) A study is being made of basic methods of measuring snow water content for use in telemetering data from remote mountain locations.
- (g) Three methods appear to offer good possibilities.
- (h) "Measurement of Snow Water Equivalent with Pressure Pillow and Neutron Moisture Probe Techniques," V. E. Penton, M. S. Thesis, Univ. of Idaho, 1964.

(3417) INFILTRATION AS AFFECTED BY FURROW PARAMETERS AND SOIL VARIABILITY.

- (b) Laboratory project; under investigation in Agricultural Experiment Station.
- (c) Assistant Prof. D. W. Fitzsimmons, Dept. of Agricultural Engineering, Univ. of Idaho, Moscow, Idaho 83843.
- (d) Theoretical; basic research.
- (e) To determine the effect of various furrow geometric parameters and soil conditions on infiltration patterns by analogy methods.
- (f) Completed.
- (g) Dimensional analysis along with electrical analog techniques was used to group the variables affecting furrow discharge into a given soil for given soil-moisture conditions into dimensionless terms. Curves were obtained showing that the hydraulic depth of a furrow can be used as a parameter for describing the effect of furrow geometry on furrow discharge. These curves also show the effects of two other geometry parameters, furrow spacing and the top width of the water surface in furrows, on furrow discharge.
- (h) "Effects of the Geometry of a Furrow Flow-System on Infiltration," D. W. Fitzsimmons and G. L. Corey. In process of publication.

(4535) CROP COEFFICIENTS FOR CONSUMPTIVE USE IN IDAHO.

- (b) Laboratory project.
- (c) Department of Agricultural Engineering, Univ. of Idaho, Moscow, Idaho 83843.
- (d) Field investigation; applied research for master's thesis.
- (e) To determine crop coefficients, using the Blaney-Criddle formula, for such crops as potatoes, beans, and corn for southern Idaho areas. The variation of the crop coefficients for (1) light, medium and heavy applications of water, (2) each month of growing or irrigation season, and (3) the stage of growth of each crop. These coefficients will be compared with the coefficients developed by Blaney-Criddle and other investigators for other areas.
- (f) Completed.
- (g) Data were obtained on consumptive use for various crops in Idaho.
- (h) "Consumptive Use Estimates for Potatoes, Beans, and Field Corn in Idaho", G. L. Corey, D. R. Kohntopp, and Galen McMaster. In process of publication.

(5167) TOTAL HYDROELECTRIC RESOURCES IN IDAHO AND DEVELOPMENT PROBLEMS ON IDAHO STREAMS.

- (b) Laboratory project.
- (d) Experimental, applied research for master's thesis.
- (e) A study of streamflow data is being made to determine full water resource capability. The study is designed to develop estimating

- constants which may give a 90 percent accuracy. New ideas for stream-to-stream diversion will be investigated.
- (h) "A Study of Hydro Peaking in Idaho", R. R. Goranson, M. S. Thesis, Univ. of Idaho 1964. "A Study of the Restraints Imposed Upon Water Resource Forecasting By the Critical-Year Concept", H. A. Stingle, M. S. Thesis, Univ. of Idaho 1964.
- (5168) INVESTIGATION OF RADIOISOTOPE SNOW GAGE COMPONENTS AND TECHNIQUES.
- (b) Laboratory project: Cooperative with Walla Walla District, Corps of Engineers.
- (d) Experimental and field investigation; applied research.
- (e) Problems of monitoring water equivalent of a snow pack using a scintillation detection system to measure attenuation of snow and water of gamma radiation are being studied. Calibration methods and variation of electronic components both under controlled laboratory conditions and remote mountain winter conditions are being considered.
- (f) Completed.
- (g) An improved system has been developed for use in a telemetering system of the Corps of Engineers in the Clearwater River drainage. Differences of attenuation by water and snow appear to be a problem the magnitude of which is yet to be determined.
- (h) "Data Conversion Systems for a Radio Isotope Snow Gage", D. L. Duncan, M. S. Thesis, Univ. of Idaho 1964.
- (5169) EFFECTS OF CONTROLLED TURBULENCE ON MASS TRANSFER.
- (b) Under NSF Grant G-17908.
- (c) Dr. Godfrey Martin, Chem. Engr. Dept., University of Idaho, Moscow, Idaho 83843.
- (d) Experimental, basic research for masters thesis.
- (e) The purpose of this work is to measure the effects of the relative intensity and integral scale of turbulence (measured previously using hot film anemometer techniques) on local mass transfer coefficients from solid cylinders involving water.
- (g) Experimental equipment has been constructed and 8 preliminary runs have been made.
- (h) "Effect of Cylinder Diameter on Local Sherwood Numbers Under Conditions of Controlled Turbulence", H. F. Litchfield, M. S. Thesis, Univ. of Idaho 1964.
- (5170) CORRELATION FOR THE DISPERSION OF LIQUIDS FLOWING THROUGH PACKED BEDS USING MODIFIED RANDOM WALK MODELS.
- (b) Laboratory project.
- (c) Dr. Godfrey Martin, Chem. Engr. Dept., Univ. of Moscow, Moscow, Idaho 83843.
- (d) Theoretical and experimental, basic research for doctor thesis.
- (e) Using an analogy to the diffusion of material fluids in turbulent flow, the relative intensity and integral scale will be obtained from experimental observation of the flow of fluids through packed beds. These parameters, normalized by dividing by the superficial velocity and packing size respectively, will be reported for different packing. The data should enable field engineers to predict the dispersion of liquids through packed beds. An attempt will be made to explain deviations from a strict random walk distribution by using other modified random walk models.
- (5368) GROUND WATER MOVEMENT IN HIGHWAY LANDSLIDES.
- (b) Laboratory project; cooperative with Idaho Dept. of Highways and Idaho Bureau of Mines and Geology.
- (c) Associate Professor of Civil Engrg., J. J. Peebles, College of Engineering, Univ. of Idaho, Moscow, Idaho 83843.
- (d) Experimental and field investigation; applied research and development with master's thesis.
- (e) To study the flow characteristics of ground water movement in landslides and to ascertain sources of the water. Tracing techniques are being studied using dyes and isotopes as well as other pressure measuring devices. This is an attempt to predict and identify slide behavior in places where slides are apt to occur.
- (g) Various dyes have been experimented with in several locations in Northern Idaho.
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- IIT RESEARCH INSTITUTE.
- (5196) TURBULENT FLOW TRANSITION NEAR SOLID AND FLEXIBLE BOUNDARIES.
- (b) BuShips Fundamental Hydromechanics Research Program administered by David Taylor Model Basin.
- (c) Mr. Henry B. Karplus, Research Physicist, 10 West 35th St., Chicago, Ill. 60616.
- (d) Experimental basic research.
- (e) Transition to turbulence is investigated in a water channel having walls with adjustable rigidity. It is intended to obtain a better understanding of the effect of resilience and damping of the walls on the build up of turbulence in boundary layers. The ultimate objective is the reduction of drag of vessels and the reduction of boundary layer noise in hydrophone domes.
- (g) Transition to turbulence is affected by wall resilience. Flexible walls may delay turbulence onset over limited flow rate regions.
- (h) Interim Technical Report No. IITRI 1205-4.
- (5538) STUDY OF VIBRATIONS INDUCED IN THIN-WALLED PIPES BY FLUID FLOW.
- (b) NASA Marshall S.F.C. Huntsville, Alabama.
- (c) Mr. Dennis W. Prosser, IIT Research Inst., 10 W. 35th St., Chicago, Ill. 60616.
- (d) Theoretical and experimental basic study.
- (e) To develop methods for predicting local vibrations induced in straight thin wall pipes due to fluid flow.
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- ILLINOIS STATE WATER SURVEY DIVISION.
- A list of publications is available upon request; write to Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (552) SEDIMENTATION OF ILLINOIS RESERVOIRS.
- (b) Laboratory project; cooperative with Agricultural Research Service, Soil Conservation Service, and University of Illinois Agricultural Experiment Station.
- (c) Mr. John B. Stall, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Field investigation; applied research.
- (e) For design of water-supply reservoirs, measurements of sediment accumulation in lakes in Illinois. Sediment samples are analyzed and complete surveys of watershed soil type, slopes, land use, and conservation practices are made.
- (g) Results show correlation between rate of sedimentation and land use on watershed; results show six factors in explaining sediment deposition: age of lake, capacity-inflow ratio, watershed gross erosion, a watershed shape factor, the density of non-incised channels, and a watershed slope factor.
- (h) "Sediment Movement and Deposition Patterns in Illinois Impounding Reservoirs," John B. Stall, State Water Survey Reprint Series No. 42, from Journal American Water Works Association, V. 65, June 1964.
- (555) EVAPORATION IN ILLINOIS.

- (b) Laboratory project.
 - (c) Mr. W. J. Roberts, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
 - (d) Field investigation; applied research.
 - (e) A 16-year record of pan evaporation data for five Illinois stations closely correlates with evaporation data computed on basis of four meteorological parameters used in Kohler's equation. Maps of lake evaporation based on 52-year records of computed evaporation are being prepared for a report on Illinois evaporation.
 - (f) Continuing.
- (559) ARTIFICIAL RECHARGE OF GROUND WATER.
- (b) Laboratory project.
 - (c) Mr. Ralph L. Evans, Peoria Laboratory, Illinois State Water Survey, Box 717, Peoria, Illinois. 61802.
 - (d) Experimental; basic research.
 - (e) Model studies of different pit types and variations in relationship between ground-water gradients and artificial recharge.
 - (f) Inactive.
 - (g) Pilot plant pit operation by Water Survey relinquished; laboratory analysis in progress.
- (560) GROUND WATER INVESTIGATION IN PEORIA, ILLINOIS, DISTRICT.
- (b) Laboratory project.
 - (c) Mr. Ralph L. Evans, Peoria Laboratory, Illinois State Water Survey, Box 717, Peoria, Illinois. 61802.
 - (d) Field investigation; applied research.
 - (e) Continuing evaluation of ground water resources of the district. Ground water levels and temperatures are monitored in wells in key locations. Effects of artificial recharge are evaluated. Analyses for changes in composition of ground water used to trace movement of ground water and to observe for possible introduction and movement of contaminants as a result of artificial recharge.
 - (g) Ground-water conditions substantially improved in past ten years and consistently since the use of four recharge pits was initiated in 1956. One pit in North Field is operated the year-round with nearly complete recovery of the recharged water. Second pit in North Field inoperative in 1962. Recharge in Central Field arbitrarily limited to cool surface water seasons. Central Field recharge has been reduced because of improved ground water conditions.
 - (h) "Thirteenth Annual Report on Operation of the Cedar Street Recharge Pits," Donald Schnepfer, Peoria Assoc. of Commerce, Peoria, Ill., 1964.
- (561) GROUND-WATER INVESTIGATION IN EAST ST. LOUIS AREA.
- (b) Laboratory project.
 - (c) Mr. R. J. Schicht, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
 - (d) Field investigation; applied research.
 - (e) Evaluation of potential yield of the sand and gravel deposits beneath the American Bottoms (East St. Louis area). Ground water levels are measured in more than 200 observation wells, 9 of which are equipped with recording gages. Ground water pumpage, Mississippi River stages, rainfall, and quality of ground water data are continuously collected. Maps have been prepared showing the distribution and areal extent of the hydraulic properties, the thickness of the aquifer, and water-table contours. The amount of recharge from precipitation and from induced infiltration of river water, and the amount of sub-surface flow from valley walls into the American Bottoms were computed by flow-net analysis of water-table maps. An electric analog model consisting of a regular array of 2800 resistors and 1350 capacitors was constructed to simulate the complex aquifer system. The accuracy and reliability of the analog model were assessed by comparing past records of water-level change and values of water-level change computed with the analog model. Excitation-response equipment, i.e., wave form generator, pulse generator and oscilloscope, was used to force electrical energy in the proper time phase into the analog model and to measure energy levels within the resistor-capacitor network. The analog model was used to estimate the practical sustained yields of existing pumping centers and to predict the potential yield of the aquifer with a selected scheme of development.
- (h) "Ground-Water Development in East St. Louis area, Illinois," R. J. Schicht, State Water Survey Report of Investigation 51, in press 1965.
- (1335) GROUND WATER INVESTIGATION IN THE CHICAGO AREA.
- (b) Laboratory project, in cooperation with Illinois State Geological Survey.
 - (c) Mr. H. F. Smith, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
 - (d) Field investigation; applied research.
 - (e) Study of variations of natural resources. Investigation of artesian well field with wells 1200 to 2200 feet deep, locally heavily pumped. Study of ground water level recession, interferences, transmissibilities, effect of additional demands.
 - (g) Results show the ground water resources in Chicago region are developed from four water-yielding units: glacial drift aquifers, shallow dolomite aquifers, Cambrian-Ordovician Aquifer, and Mt. Simon Aquifer. The Cambrian-Ordovician has been the most highly developed source of large ground-water supplies. Future ground-water supplies should be taken from the shallow aquifers wherever possible.
 - (h) Ground Water Supplies of Northeastern Illinois, Joint Discussion: "Quality Problems in Well Waters," by T. E. Larson; "Potential Yield of Aquifers and Ground Water Pumpage," by W. C. Walton, State Water Survey Reprint Series No. 38, from Journal American Water Works Association, V. 56 (2): 169-188, February 1964.
 - "Ground-Water Pumpage in Northeastern Illinois through 1962," R. T. Sasman, State Water Survey Report of Investigation 50, in press 1965.
- (1665) HYDRAULIC DESIGN OF DROP-INLET SPILLWAY STRUCTURES FOR SMALL RESERVOIRS.
- (b) Laboratory project, in cooperation with Agricultural Research Service, Soil Conservation Service, and Illinois Agricultural Experiment Station.
 - (c) Mr. H. W. Humphreys, Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
 - (d) Experimental; generalized applied research for development and design.
 - (e) To determine the most desirable proportions and shapes of drop-inlet spillway structures that have unique flow characteristics and to develop anti-vortex devices. To provide the necessary information on flow relations and discharge coefficients so that these structures may be economically designed. Initial phases of study concerned with hydraulics of square risers with free discharge. Effect of lip or crest shape and anti-vortex devices being studied. Second phase to include the complete spillway. Experimental apparatus constructed and tests are being conducted on the complete spillway. Information is being obtained on discharges, vortex effect on discharge, pressures, a flat plate anti-vortex device, and flow conditions.
 - (g) Hydraulics of various types of flow possible in square risers are well defined as well as some of the effect of non-square crest

shape. Model tests were performed on a drop-inlet spillway to determine whether or not a metal grating deck placed above the inlet can control vortices. The results of the tests show that gratings do not prevent or control strong vortices.

(2532) EVAPORATION RETARDATION.

- (b) Laboratory project.
- (c) Mr. W. J. Roberts, Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
- (d) Field investigation; applied research, design.
- (e) Monomolecular chemical films to retard evaporation from water supply lakes and ponds in Illinois.
- (f) Additional tests planned.
- (g) 1963-64 results with soluble packets were favorable. Cooperation with lake owners to be continued in 1965.

(2534) DENSE RAIN GAGE NETWORK PROJECTS.

- (b) Laboratory project.
- (c) Mr. G. E. Stout, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Field investigation; applied research.
- (e) Data from three rain gage networks, consisting of 50 gages in 400 square miles, 97 gages in 1220 square miles, and 20 gages in 10 square miles. Studies include: (1) Rainfall variability, (2) frequency of point and areal mean rainfall, (3) area-depth relations, (4) variation of point rainfall with distance, (5) areal representativeness of point rainfall, and (6) reliability of areal mean rainfall estimates.

(2535) FILTERING THROUGH COARSE MATERIALS.

- (b) Laboratory project.
- (c) Mr. Ralph L. Evans, Peoria Laboratory, Illinois State Water Survey, Box 717, Peoria, Illinois. 61802.
- (d) Experimental; basic research.
- (e) Small, coarse media (1/4 - to 3/4-inch) filters are operated at rates comparable to those achieved in field practice. Purpose is to study the effects of coarse media on physical, chemical, and bacteriological properties of recharged water and to evaluate the function of coarse media in protecting aquifer materials.
- (g) Results of former field tests of various sizes of materials are reported in State Water Survey Bulletin 48. Program of specially controlled laboratory test runs initiated in 1962 under grant from U. S. Public Health Service.

(2788) METEOROLOGY OF FLOOD-PRODUCING STORMS.

- (b) Laboratory project.
- (c) Mr. F. A. Huff, Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
- (d) Applied research.
- (e) Investigation of meteorological conditions associated with flood-producing storms in Illinois to obtain basic data for reliable definition of time and space distribution of such storms and for calculation of probable maximum rainfall.
- (g) Continuing project; analysis of storm area-depth relations, orientation of storms, seasonal and geographic distribution, synoptic weather types, topographic influences. Development of area-depth frequency relations underway.

(3058) HYDROMETEOROLOGICAL ANALYSIS OF SEVERE RAINSTORMS.

- (b) Laboratory project.
- (c) Mr. F. A. Huff, Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
- (d) Field investigation; applied research.
- (e) Field surveys and detailed analyses of severe rainstorms in Illinois. Analyses based upon radar, synoptic weather, and field survey data

and include area-depth-duration relations, antecedent rainfall evaluation, isohyetal maps for peak periods of storm.
(f) Suspended, for lack of qualifying storms.
(g) Analyses completed on 16 storms since 1951.
(h) State Water Survey Reports of Investigation Nos. 14, 24, 27, 35, and 42.

(3059) THERMAL LOADINGS AND CHARACTERISTICS OF SURFACE WATERS.

- (b) Laboratory project.
- (c) Mr. Ralph L. Evans, Peoria Laboratory, Illinois State Water Survey, Box 717, Peoria, Illinois. 61802.
- (d) Field investigation; applied research.
- (e) A study of heat loads applied to fresh water bodies in Illinois to determine relationships between temperature and/or heat loadings, water usage, stream assets, and stream recovery capabilities.
- (h) "Temperatures of Surface Waters in Illinois," Robert H. Harneson and Virginia M. Schnepfer, State Water Survey Report of Investigation 49, 1965, in press.

(3421) PILOT DRAINAGE BASIN STUDIES IN NAPERVILLE AREA.

- (b) Laboratory project.
- (c) Mr. R. J. Schicht, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Field investigation; applied research.
- (e) All factors of the hydrologic cycle (especially precipitation, temperature, stream flow, soil moisture, changes in surface and subsurface storage, and evaporation) to be measured and examined to obtain quantitative knowledge of the movement and storage of ground water under natural conditions in the 22-square mile basin. The annual rate of recharge to, and evapotranspiration from, the ground-water reservoir to be determined. Stream discharge hydrograph to be separated into its two components, surface runoff and ground-water runoff. Gravity yields of glacial deposits and underlying dolomite aquifer to be estimated.

(3420) FREQUENCY AND DURATION OF LOW FLOWS.

- (b) Laboratory project.
- (c) Mr. John B. Stall, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Theoretical; applied research.
- (e) Analysis of the severity, frequency, and duration of low flows in Illinois streams as they affect impounding reservoir yields. Methodology devised to determine gross and net yield of an impounding reservoir during various recurrence-interval droughts. A non-sequential mass curve analysis gives gross yield. Net lake evaporation is processed on a frequency basis; applied to the reservoir; and net yield is determined. Risks associated with an impounding reservoir have been determined and clarified to allow better understanding of reservoir design and recurrence of events.
- (h) "Low Flows of Illinois Streams for Impounding Reservoir Design," John B. Stall, State Water Survey Bulletin 51, 1964.

(3731) HYDROLOGY OF DOLOMITE AQUIFERS.

- (b) Laboratory project, in cooperation with Ill. State Geological Survey.
- (c) Mr. R. J. Schicht, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Field investigation; applied research.
- (e) Evaluation of water yielding potential of dolomite aquifer in Illinois from pumping test and specific capacity data is in progress. Statistical analysis of well production data is being made to determine geological controls on aquifer productivity.
- (g) Frequency graphs were used to determine the role of individual units of dolomite aquifers in northern Illinois, as contributors of ground water. Statistical

- analysis of specific-capacity data provided a basis for determining whether or not significant relationships exist between the yields of wells and geohydrologic controls. Probable ranges in yields of shallow dolomite wells in undeveloped areas in northern Illinois were estimated from specific-capacity frequency graphs, aquifer thickness and areal geology maps, and water-level data. The practical sustained yield of the dolomite aquifer in DuPage County was estimated based largely on case histories of heavy ground-water development.
- (h) "Yields of Shallow Dolomite Wells in Northern Illinois," Sandor Csallany and W. C. Walton, State Water Survey Report of Investigation 46, 1963.
- (3732) TRANSPIRATION RETARDATION.
- (b) Laboratory project.
- (c) Mr. W. J. Roberts, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Laboratory and field investigation.
- (e) Monomolecular film-forming fatty alcohols are introduced to soils and roots of plants causing a reduction in evapotranspiration. Field tests being analyzed.
- (g) "Can Fatty Alcohols Reduce Water Losses?" J. P. Vavra and W. J. Roberts, Crops and Soils, June-July 1964.
- (3733) EVALUATING WELLS AND AQUIFERS WITH ANALYTICAL METHODS.
- (b) Laboratory project.
- (c) Mr. R. J. Schicht, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Field investigation; applied research.
- (e) Case histories of ground-water development are being studied to determine if it is possible to evaluate wells and aquifers with analytical expressions by devising approximate methods of analysis based on idealized models of aquifer situations. Geohydrologic boundaries are assumed to be straight-line demarcations and are given mathematical expression by means of the image-well theory. The hydraulic properties of the aquifer and overlying confining beds are considered mathematically by using ground-water formulas. Records of past pumpage and water levels and a digital computer are used to establish the validity of this mechanism to describe the response of aquifers to pumping.
- (g) Case histories of ground-water development have been used to evaluate the practical sustained yields of aquifers in the Chicago region, the Havana Lowlands region, the Embarras River Basin, and in the areas of Arcola, Taylorville, Tallula, Assumption, Pekin, Joliet, Woodstock, Libertyville, Chicago Heights and LaGrange.
- (h) "Ground-water Development in Several Areas of Northeastern Illinois," T. A. Prickett, L. R. Hoover, W. H. Baker, R. T. Sasman, State Water Survey Report of Investigation 47, 1964.
- "Preliminary Report on Ground-Water Resources of the Havana Region in West-Central Illinois," W. Walker, R. E. Bergstrom, and W. C. Walton, State Water Survey and Geological Survey Cooperative Ground-Water Report 3, 1965.
- "Potential Yield of Aquifers in Embarras River Basin, Illinois," W. C. Walton and Sandor Csallany, State Water Survey Report of Investigation in preparation.
- (3734) INDUSTRIAL WATER USE IN ILLINOIS.
- (b) Laboratory project.
- (c) Mr. Ralph L. Evans, Peoria Laboratory, Illinois State Water Survey, Box 717, Peoria, Illinois 61802.
- (d) Field investigation; applied research.
- (e) Determine withdrawal of water by industries in Illinois, with delineation according to kinds of industry, location by area, and sources of supply.
- (f) Project reactivated.
- (4135) CORROSION PREVENTION BY CaCO_3 .
- (b) Laboratory project.
- (c) Mr. T. E. Larson or H. W. Humphreys, Illinois State Water Survey, Box 232, Urbana, Ill. 61802
- (d) Experimental.
- (e) To determine chemical requirements and velocity requirements to provide protective coating in water pipes.
- (4137) DIURNAL DISTRIBUTION OF PRECIPITATION AND RELATED WEATHER ELEMENTS.
- (b) Laboratory project.
- (c) Mr. S. A. Changnon, Jr., Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Applied research.
- (e) Investigation of the diurnal distribution of various weather elements on a monthly, seasonal, annual, and geographic basis. Elements under study include rainfall, sleet, hail, tornadoes, thunderstorms, freezing rain, and fog.
- (f) Suspended.
- (4138) EVAPOTRANSPIRATION IN ILLINOIS.
- (b) Laboratory project.
- (c) Mr. D. M. A. Jones, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Applied research.
- (e) Evaluation of methods for calculating evapotranspiration and assessment of evapotranspiration in Illinois.
- (4139) PRECIPITATION PATTERNS OVER AND AROUND LOWER LAKE MICHIGAN.
- (b) Laboratory project.
- (c) Mr. G. E. Stout, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Applied research.
- (e) Radar film records are being studied to determine the influence of Lake Michigan on precipitation processes.
- (f) Suspended.
- (4536) GEOHYDROLOGIC SYSTEM ANALYSIS WITH AN ELECTRIC ANALOG COMPUTER.
- (b) Laboratory project.
- (c) Mr. R. J. Schicht, Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
- (d) Experimental; applied research.
- (e) Purpose of project is to apply electric analog computers to ground-water resource evaluation problems in Illinois. Ground-water development schemes are being tested and the relative merits of alternate choices of development are being appraised. The consequences of the utilization of aquifers are being forecast. The electric analog computer in use consists of an analog model and excitation-response apparatus, i.e., waveform generator, pulse generator, and oscilloscope. The analog model is a regular array of resistors and capacitors and is a scaled-down version of an aquifer.
- (g) Analog models have been constructed for three idealized aquifer situations to study the accuracy and reliability of the analog computer. Close agreement between analog computer and exact analytical solutions for the three selected aquifer situations has been obtained. A comparison of the analog computer and simplified analytical solutions for a selected complex aquifer situation indicates that resource evaluations based on incomplete data and analog or idealized mathematical models can be meaningful and useful. Analog models for sand and gravel aquifers in the East St. Louis and Champaign-Urbana areas have been constructed. Past records of pumpage and water levels have been used to establish the validity of the analog model for the East St. Louis area.
- (h) "Hydrogeologic Electric Analog Computers," W. C. Walton and T. A. Prickett, Journal of

the Hydraulics Division, ASCE, V. 89, (Hy 6)
67-91, November 1963.

(4537) HYDROMETEOROLOGY OF SPECIFIC ILLINOIS BASINS.

- (b) Laboratory project.
- (c) Mr. F. A. Huff, Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
- (d) Applied research.
- (e) Development of relations defining the distribution of precipitation extremes in major basins. Included are studies of the frequency distribution of excessive point and areal mean rainfall in various regions of basins, the frequency distribution of drought, average slope of area-depth curves, actual depth-duration-area relations in the heaviest storms on record, area-depth frequency relations based upon all major storms of record, seasonal distribution of heavy storms, and the shape characteristics of major storms.
- (h) "Hydrometeorology of the Kaskaskia Basin," F. A. Huff, Report of Investigation in preparation.

(5051) GROUND-WATER RECHARGE AND RUNOFF IN ILLINOIS.

- (b) Laboratory project.
- (c) Mr. R. J. Schicht, Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
- (d) Field investigation; applied research.
- (e) Purpose of project is to describe recharge conditions throughout the state and to determine the relation between ground-water contribution to streams and basin characteristics.
- (g) Recharge rates for several aquifers in Illinois have been estimated based on flow-net analyses of piezometric surface maps. Recharge rates vary with vertical hydraulic gradients and are not constant but vary in space and time. Annual ground-water runoff from 109 drainage basins scattered throughout Illinois was estimated with streamflow hydrograph separation methods and flow-duration curves. The relations between ground-water runoffs during years of near, below, and above normal precipitation and basin characteristics such as geologic environment, topography, and land use were determined by statistical methods. Studies indicate that no simple relation exists between ground-water runoff and the potential or practical sustained yields of aquifers.
- (h) "Estimating the Infiltration Rate of a Stream-bed by Aquifer-Test Analysis," W. C. Walton, State Water Survey Reprint Series No. 37, extract of Publication 63, I.A.S.H., pp. 409-420, Berkeley 1963.
"Ground-water Recharge and Runoff in Illinois," W. C. Walton, State Water Survey Report of Investigation 48, in press 1965.

(5052) COMPARATIVE RAINGAGE STUDY.

- (b) Laboratory project.
- (c) Mr. D. M. A. Jones, Illinois State Water Survey, Box 232, Urbana, Ill. 61802
- (d) Applied research.
- (e) Field comparison of shielded and unshielded recording and nonrecording precipitation gages including the WMO International Reference Precipitation Gage.
- (h) Report on three years of data prior to installation of WMO gage in preparation.

(5053) CLIMATOLOGICAL ANALYSIS OF SEVERE WINTER STORMS.

- (b) Laboratory project.
- (c) Mr. Stanley A. Changnon, Jr., Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
- (d) Applied research.
- (e) Detailed analyses of severe winter season snowstorms, sleet and ice storms. Analyses based primarily on U. S. Weather Bureau original station records for Illinois during the 1900-1962 period. Temporal and areal frequencies, storm movement, shapes,

orientations, duration, and individual maps for each storm.

(f) Continuing project.

(g) Analysis partially completed on all storms in 1900-1957 period.

(5322) SURFACE WATER STORAGE POTENTIAL.

- (b) Laboratory project.
- (c) Mr. J. H. Dawes, Illinois State Water Survey, Box 232, Urbana, Illinois 61802.
- (d) Field investigation; applied research.
- (e) A statewide study of surface water storage potential, from interrelated projects including evaluations of hydrologic, geologic, and physical characteristics. Results will furnish an evaluation of potential increases in useable water supplies by storage of excess water during floods or rainy periods. State has been divided into five parts for this study. The 16 southern counties were included in an earlier study. (Report of Investigation 31, 1957); a report for the 29 counties in south-central Illinois in preparation.
- (g)

ILLINOIS STATE WATERWAYS DIVISION, Springfield.

(1863) EROSION CONTROL, ILLINOIS SHORE OF LAKE MICHIGAN.

- (b) State of Illinois.
- (c) Mr. John C. Guillou, Chief Waterway Engr., Div. of Waterways, Dept. of Public Works and Buildings, 201 West Monroe Street, Springfield, Illinois 62706.
- (d) Field investigation; applied research.
- (e) To obtain and correlate basic data on the several forces and factors involved in erosion processes along the Illinois Shore of Lake Michigan to the end that future efforts toward the prevention of erosion might be founded upon a more definite and factual basis with a consequent greater degree of assurance that the works will serve the intend purposes.
- (g) No significant results since last report.

(5548) SOLDIER CREEK CHANNEL MODEL.

- (b) State of Illinois.
- (c) Mr. John C. Guillou, Chief Waterway Engr., Div. of Waterways, Dept. of Public Works and Buildings, 201 West Monroe Street, Springfield, Illinois 62706.
- (d) Experimental applied research.
- (e) A hydraulic model study is being conducted to determine the practicability of increasing the channel capacity of Soldier Creek thru Kankakee by enlarging, realining and concrete lining the rock channel in order to reduce damaging flood stages.

(5549) ILLINOIS RIVER.

- (b) State of Illinois.
- (c) Mr. John C. Guillou, Chief Waterway Engr., Div. of Waterways, Dept. of Public Works and Buildings, 201 West Monroe Street, Springfield, Illinois 62706.
- (d) Experimental applied research.
- (e) A hydraulic model study is being conducted to determine the effects, on the Upper Illinois River, of various flood relief measures proposed for the Illinois Waterway and Chicago Sanitary and Ship Canal.

UNIVERSITY OF ILLINOIS, Soil and Water Conservation Engineering Lab., Department of Agricultural Engrg.

Inquiries concerning the following projects should be addressed to Prof. B. A. Jones, 100 Agricultural Engineering, University of Illinois, Urbana, Ill.

(2316) RUNOFF FROM SMALL AGRICULTURAL AREAS IN

ILLINOIS.

- (b) Laboratory project cooperative with ARS, U. S. Department of Agriculture.
- (d) Experimental and field investigation; basic research.
- (e) To determine frequencies of peak rates and total amounts of runoff from agricultural watersheds of 25 to 1,500 acres; to determine maximum rates of runoff from agricultural watersheds in different soil association areas in Illinois; to compare runoff from agricultural watersheds under accepted soil conservation practices with watersheds cultivated without soil conservation practices. Watersheds of 45.5, 63, 82, and 390 acres near Monticello, Illinois are covered with a rain gage network, and runoff is measured at weirs and spillway structures by water level recorders. Maximum stage recorders are installed at field structures on 8 watersheds in Champaign, Piatt, Vermillion, and Ford Counties on watersheds ranging in size from 45 to 1,400 acres. Model studies and field calibrations are made on the field structures.
- (2789) LABORATORY MODEL STUDIES OF CONSERVATION AND DRAINAGE STRUCTURES.
- (b) Laboratory project.
- (d) Experimental investigation in the laboratory; applied and basic research.
- (e) To investigate the performance of soil and water conservation structures by means of hydraulic model studies, to study water flow patterns into surface drains and to determine the cause of failures and remedial measures of certain conservation structures under flood conditions.
- (h) "Tractive-Force Distribution in Sewers and Channels," J. A. Replogle, Ph.D. thesis 1964. Available in University Library.
- "Tractive-Force Distribution in Open Channels," J. A. Replogle and V. T. Chow. Manuscript submitted for publication in Proc. ASCE, Journ. of the Hydraulics Division.
- Discussion of "Natural Roughness Effects in Rigid Open Channels," R. N. Fenzl and J. R. Davis. Proc. ASCE 90:HY 3, 351-359, 1964.
- "Hydraulics Resistance Relationships for Surface Flows in Vegetated Channels," R. N. Fenzl and J. R. Davis. Trans. ASAE 7:1 46-57, 55. 1964.
- (3424) A STUDY OF RAINFALL ENERGY AND SOIL EROSION.
- (b) Laboratory project cooperative with ARS, U. S. Dept. of Agriculture.
- (d) Experimental; basic research.
- (e) Natural rainstorms are photographed with a raindrop camera so that the number of raindrops, their size and size distribution, and the kinetic energy of a rainstorm may be calculated. Physical measurements will be made of the soil to determine the effect of the kinetic energy of the rainstorm on soil loss. The nature and properties of rainstorms that occur in this area of Illinois will also be studied.
- (h) "The Erosion-Control Effectiveness of Rotation Meadows," J. V. Manning, L. C. Johnson, L. D. Meyer and B. A. Jones. Journ. Soil and Water Conserv. 19-3: 91-95, 1964.
- (4986) WATER INFILTRATION RATE METHODS AND DETERMINATIONS ON SOILS.
- (b) Laboratory project.
- (d) Field investigation, basic research.
- (e) To field test practical methods for determining and predicting relative infiltration rates of soils during irrigation and during rains. To determine infiltration rates for specific soil types under various management practices.
- (4987) THE EFFECT OF GYPSUM AND DRAINAGE ON SOLONETZIC SOILS (SLICK-SPOTS) IN ILLINOIS.
- (b) Laboratory project in cooperation with Dept. of Agronomy.
- (d) Experimental field investigation.
- (e) To test the feasibility of replacing and removing excess sodium from solonetzic soils under field conditions with (a) different methods and rates of applying gypsum (calcium sulphate), (b) different degrees of disturbing the subsoil, and (c) different spacings of tile drains.
- Twenty plots were established in a random pattern to compare 3 positions for the application of gypsum and 3 spacings of tile drains with check plots. The tile effluent is measured by recording equipment to determine the rate and volume of flow. Also samples will be taken to determine the amount of sodium in the leachate.
- (5369) HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS.
- (b) A laboratory project.
- (d) Experimental and theoretical; basic research.
- (e) The objective is to select a method for integrating the partial differential equations which will form a part of the mathematical model for watersheds.
- (g) Solutions for the following continuity and momentum equations for unsteady, spatially varied flow in a wide channel were obtained by numerical integration using the IBM 7094 computer:
- $$\frac{\partial y}{\partial t} + u \frac{\partial y}{\partial x} + y \frac{\partial u}{\partial x} = R \quad (1)$$
- $$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + g \frac{\partial y}{\partial x} = g (S_0 - S_f) - \frac{uR}{y} \quad (2)$$
- in which
- y = depth of flow, varying with time and position along the channel
- u = average velocity associated with the depth y
- g = gravitational constant
- S₀ = channel slope
- R = rate of inflow per unit channel area
- S_f = energy gradient of the flow
- x = distance along the channel
- t = time
- The initial condition for the problems solved was a dry bed (no flow). The boundary conditions were no inflow at the head of the channel, and a free overfall at the lower end with subcritical flow upstream. Results were obtained for each of three finite difference approximations of equations 1 and 2 essentially as originally proposed by Isaacson, Stoker, and Troesch. The space and time increments, Δx and Δt, used in representing the derivatives were subject to the interrelationship imposed by the method of characteristics.
- Although the laboratory model to be used for checking the numerical results has not been completed, an independent method of calculation was used to determine the equilibrium depth profile for given boundary conditions. The transient profiles approached the equilibrium profile satisfactorily over the upper two-thirds of the channel. All three methods proved to be unstable, however, in the region of greatly accelerated flow near the discontinuity at the free overfall. Reduction of the magnitude of the space increment, Δx, would improve the evaluation of the terms for ∂u/∂x and ∂y/∂x, possibly improving the results immediately upstream from the overfall at the expense of a required reduction in the magnitude of Δt. The application of least square polynomial smoothing to each generated profile prior to calculation of the succeeding profile effectively damped the oscillations of the solutions, but also had a cumulative effect which gradually distorted the shape of the calculated water surface profiles.

UNIVERSITY OF ILLINOIS, Hydraulics and Water Resources Laboratory, Department of Civil Engrg.

Inquiries concerning all projects should be addressed to Dr. V. T. Chow, Prof. of Hydraulic Engineering, University of Illinois, Urbana, Ill., 61803, unless otherwise indicated.

(4537) BOX CULVERT ENERGY DISSIPATORS.

- (b) Laboratory project.
- (c) Prof. M. B. McPherson, Dept. of Civil Eng., Univ. of Ill., Urbana, Illinois.
- (d) Experimental; applied research; NSF undergraduate research grant problem, and M. S. Thesis.
- (e) To analyze all classes of energy dissipators which may be suitable for culverts, and development of new devices for optimum overall hydraulic performance are the ultimate goals of this study.
- (g) An analysis and experimental investigation of the U. S. Bureau of Reclamation Basin VI energy dissipator used in conjunction with a box culvert has been completed. Criteria for classification and evaluation of energy dissipators for culverts have been established.
- (h) "Energy Dissipators for Spillways and Outlet Works," by M. B. McPherson et al. Proceedings ASCE, Journal of the Hydraulics Div., 90:HY1 (1964), pp. 121-147.

(4538) WATER DISTRIBUTION SYSTEMS-ANALYSIS CRITERIA.

- (b) N. I. H. Research Grant.
- (c) Prof. M. B. McPherson, Dept. of Civil Eng., Univ. of Illinois, Urbana, Illinois.
- (d) Numerical; development.
- (e) Exploitation of previously developed generalized relations describing network head losses in a concise analytical form makes possible comprehensive system analyses, balancing pump-network-storage characteristics for optimization of a composite system design.
- (g) The feasibility and comparative cost of various operating options have been determined. Using a computer, system parameter combinations for given demand schedules have been studied, and results have been succinctly defined in simple representations. Simple analogous demand schedules, such as sine distributions, are being studied so that results can be completely generalized. More complex hydraulic cases will also be investigated. Mathematical proofs and practical limitations of basic network and system parameters are being developed. Using statistical techniques, the possibility of simulating future demand schedules for general use in analysis, design, and operation will be studied.
- (h) Communication on "Distribution Analysis by Electronic Computer," by M. B. McPherson, Journal of Institution of Water Engineers (London), 17:2 (1963), pp. 130-134.

(4539) NON-UNIFORM SUPPLY OVERLAND FLOW.

- (b) Laboratory project; support from University of Illinois Research Board.
- (c) Prof. M. B. McPherson, Dept. of Civil Eng., University of Illinois, Urbana, Illinois.
- (d) Experimental and theoretical; applied research.
- (e) The dimensionless overland flow hydrograph given by Izzard, including recession characteristics, has been investigated for uniform rainfall excess intensities. The suitability of Izzard's procedures for estimating hydrographs for nonuniform intensities has been studied, as well as other numerical procedures. Data were obtained from laboratory measurements, using both a smooth and uniformly rough surface.

(4541) VARIATION OF TRACTIVE FORCE IN SEWERS AND DRAINS.

- (b) Laboratory project for J. A. Replogle's

- (d) doctoral thesis directed by V. T. Chow. Experimental and theoretical.
- (e) To study the distribution of boundary shearing stress, or tractive force in a circular conduit flowing partially full and to determine the relationship between the shearing-stress distribution and the velocity distribution.
- (g) The solution of the problem is based on the assumption that a turbulent flow in the channel has a uniform velocity distribution modified by boundary effects and turbulent mixing. The boundary effects are further considered to consist of two additive components, namely, viscous effects and the secondary effects caused by the restraint of the turbulent fluctuations at the walls and the surface. The velocity of flow normal to the channel cross section is therefore expressed as the weighted sum of two functions of the Poisson equation type. The relative influence of the two functions of the total flow is defined experimentally for the relationship of the weighted coefficient to channel geometry and roughness. The experimental determination of the coefficient is accomplished by using a smooth copper pipe and a rough steel pipe. The tractive force distribution is determined by a "law-of-the-wall" method and with the Preston technique using Pilot tubes calibrated in place. The equations are solved by the finite-differences method using the digital computer to evaluate the weight coefficient in the Poisson equations for both smooth and rough pipes. The relations developed from this investigation compare favorably with some published velocity distributions including those obtained by Bazin.
- (h) "Tractive Force Distribution in Sewers and Channels," by J. A. Replogle, Ph.D. thesis directed by V. T. Chow, Dec. 1963.

(4543) WATER RESOURCES SYSTEM ANALYSIS.

- (b) Laboratory project supported by the University's Center for Advanced Study.
- (d) Theoretical; basic research.
- (e) To use the operations research techniques to optimize water resources system for the planning and development of water projects, by utilizing mathematical models and simulation. Optimization is made by deterministic and stochastic linear programming and dynamic programming, considering various types of constraints including economic efficiency and budget limitations. For mathematical simulation, both random sampling and systematic sampling are considered, and additional hydrologic data are generated sequentially by means of Monte Carlo methods and Markov chain models. Study of the reservoir design is also made by using queueing theory through the use of the sequentially generated stochastic input flow information.
- (h) "Water-Resources System Design by Operations Research", by V. T. Chow, Section 26-II in "Handbook of Applied Hydrology," edited by V. T. Chow, McGraw-Hill Book Co., N. Y., 1964.

(4905) WATER WAVE AND STRUCTURE INTERACTION.

- (b) Laboratory project supported by the NSF undergraduate research grant and University of Illinois Research Board.
- (c) Prof. J. P. Murtha, Dept. of Civil Engineering, Univ. of Illinois, Urbana, Illinois.
- (d) Experimental; basic research.
- (e) To study the time variation of forces produced by gravity waves on coastal and offshore structures and to evaluate the subsequent structural motion. The effort involves laboratory studies of wave-structure interaction as well as analytical investigations.
- (g) During the past year, laboratory equipment for small-scale investigations has been constructed, and experimental data relating

to type of disturbance and subsequent wave characteristics have been obtained.

(4906) BASIC INVESTIGATION ON WATERSHED HYDRAULICS.

- (b) National Science Foundation research project.
- (d) Experimental and theoretical; basic research.
- (e) To investigate the basic laws governing the flow of surface water over drainage basins by controlled experiments on geometric basins. By controlling the various factors involved in the mechanics of flow, the experimental data so obtained can be more amenable to theoretical analyses for the determination of the basic laws. In addition to the shape of the geometric basin, other characteristics including slope, size, surface roughness, channel storage, channel density, etc., will be studied. The input rainfall excess is to be simulated by electronically controlled sprinkling systems composed of a large number of modules so that different patterns of rainfall supply and even the effect of the movement of rain-making clouds can be produced artificially. The output discharge from the basin is to be measured by electronic sensing devices which can automatically be digitized for the computer to construct the hydrographs of outflow.
- (g) During the year, effort has been made to design the rainfall simulator system which is composed of 100 modules. Each module is a box of 4 feet by 4 feet in size with numerous holes on the bottom. By controlling the inside pressure of the box, artificial raindrops are produced. The whole system is supported by a metal frame of 40 feet by 40 feet in size.

(4907) A BASIC STUDY OF THE LINEARITY OF THE RAINFALL-RUNOFF PROCESS IN WATERSHEDS.

- (b) Laboratory project for M. H. Diskin's doctoral thesis directed by Prof. V. T. Chow.
- (d) Theoretical; basic research.
- (e) To investigate the nonlinearity of the hydrograph theory by studying the properties of the kernel function in the Duhamel convolution integral via the properties of its Laplace transform. The Laplace transform of the kernel function is the transfer function of the drainage basin system.
- (g) To facilitate the comparison of transfer functions and to accentuate the differences between transfer functions obtained from various storms and basins, a special form transfer function is developed, which is dimensionless and eliminates the location of the centroid of the kernel function. By means of this complex mathematical transformation, various conceptual models for rainfall and runoff process in drainage basins can be easily compared, and the nonlinearity of the actual basin process can be evaluated. The method developed from the proposed theory is tested with 31 storm records of rainfall and runoff for 14 drainage basins with areas ranging from 30 to 1,420 square miles. The result indicates that the instantaneous unit hydrograph varies systematically but nonlinearly with the storms, but there is also a random component superimposing on the process.
- (h) "A Basic Study of the Linearity of the Rainfall Runoff Process in Watersheds," by M. H. Diskin, Ph.D. thesis directed by V. T. Chow, Jan. 1964.

(4908) THE FORCES CAUSED BY WAVES BREAKING AGAINST VERTICAL IMPERVIOUS RIGID WALLS.

- (b) Laboratory project for a doctoral thesis by W. J. Garcia, Jr., under the direction of Prof. V. T. Chow cooperative with U. S. Army Engineers Waterways Experiment Station.
- (d) Experimental and analytical; basic research.
- (e) To formulate relations which will enable one to determine pressures on impervious rigid

walls due to breaking waves with sufficient accuracy to afford an economical and safe design for sea walls and breakwaters; also to investigate the variation of pressure on the wall with respect to time and spacial distribution.

- (g) During the year five different wave conditions were investigated. The wave characteristics and pressure distribution on the face of the model wall for each of the wave conditions were measured. With the cooperation of the U. S. Army Engineers, the experimental work is being conducted at the U. S. Army Waterways Experiment Station.

(4909) A STUDY OF THE EFFECT OF BASIN STORAGE ON SURFACE RUNOFF HYDROGRAPHS.

- (b) Laboratory project for V. C. Kulandaiswamy's doctoral thesis under the direction of Prof. V. T. Chow.
- (d) Theoretical; basic research.
- (e) To study the drainage basin taken as a lumped hydrologic system.
- (g) Assuming a general nonlinear equation for the basin storage and combining it with the equation of continuity, a differential equation for the system is formulated. The equation is quasi-linearized by assuming that the coefficients are functions of the average inflow and outflow of the system. Solution of the resulting equation produces four possible conceptual system models depending on the nature of the roots of the equation. Storms and the corresponding outflow hydrographs over six natural drainage basins varying from 7.16 to 1,141 square miles are analyzed by the proposed equation and theory. From the results of the analysis it is seen that three coefficients of the proposed equation vary with the outflow, thus indicating nonlinearity, while the remaining two coefficients do not change much and can be assumed constant. A study of the variation of the three coefficients seems to indicate that they decrease exponentially with the peak runoff. The storage equation derived in this study is shown for use in flood routing and it is proposed also for use in infiltration analysis.
- (h) "A Basic Study of the Rainfall Excess-Surface Runoff Relationship in a Basin System," by V. C. Kulandaiswamy, Ph.D. thesis directed by V. T. Chow, March 1964.

(4910) PROBABILITY AND SYNTHETIC HYDROLOGY APPROACH TO THE ANALYSIS OF RAINFALL-RUNOFF FREQUENCY RELATIONSHIP.

- (b) Laboratory project for S. Ramaseshan's doctoral thesis directed by Prof. V. T. Chow.
- (d) Theoretical; basic research.
- (e) To treat the inflow into a basin as a stochastic input, the basin as a linear system, and the outflow as the response of the basin to the input and to investigate the stochastic behavior of the system by sequential generation and simulation techniques.
- (g) The 28-year records of annual storm and flood from the French Broad River at Bent Creek, North Carolina, covering a drainage area of 676 sq. mi. are mainly used in the analysis. First, statistical Markov models using shifting technique for the precipitation process in the annual storms are formulated and tested, and their parameters are evaluated. Using Monte Carlo method, 1,000 years of sequentially generated storms are produced. The effective storm rainfalls are routed through a conceptual mathematical model consisting of a series of linear reservoirs. By considering the rainfall abstractions to consist of a deterministic component and a random component, a good agreement is obtained between the historical flood frequencies. Finally, stochastic flood duration curves are developed and

- recommended for water resources design purposes.
- (h) "A Stochastic Analysis of Rainfall and Runoff Characteristics by Sequential Generation and Simulation," by S. Ramaseshan, Ph.D. thesis directed by V. T. Chow, April, 1964.
- (5289) STOCHASTIC HYDRODYNAMIC ANALYSIS OF OCEAN WAVE ACTIONS ON MOORED PLATFORM FOR UNDERWATER MISSILE LAUNCHING.
- (b) Laboratory project for a doctoral thesis by B. J. Muga, under the direction of Prof. V. T. Chow cooperative with U. S. Navy Civil Engineering Laboratory.
- (d) Experimental and analytical; basic and applied research.
- (e) To analyze the motions and forces induced by irregular waves on a construction type platform as moored in the open Pacific Ocean.
- (g) Prototype and model tests are conducted on the platform, named "Fishhook," which is of the catamaran design, having a displacement of 850 tons. It is spread-moored by four 2 1/2-inch stud link chains in 165 feet of water. Water level fluctuations, ship rotations and accelerations, mooring forces, and wind speed and directions are measured. Both prototype and model tests data are analyzed in the form of amplitude response operations by the spectrum and cross-correlation analyses of the complex time series histories. The results are compared with the linear theory of ship's motion. Equations of motion of the system for sinusoidal waves are formulated on the basis of the slender body theory for 6 degrees of freedom, taking into account both hydrostatic and hydrodynamic effects. The excitation functions and the various coefficients in the equations are obtained for surges, heaves, pitches, sways, rolls, and yaws. Solutions are also given to the forces in the mooring cables and the horizontal force components and the yawing moment induced by the mooring system on the platform.
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- UNIVERSITY OF ILLINOIS, Fluid Mechanics and Hydraulics Laboratory.
- Inquiries concerning Project No. 2083 should be addressed to W. M. Lansford, 219 Talbot Laboratory, University of Illinois, Urbana, Illinois, and for Projects Nos. 2536, 3427, 4142, 4558 to Professor J. M. Robertson, 125 Talbot Laboratory, Univ. of Illinois, Urbana, Illinois.
- (2083) VELOCITY DISTRIBUTION IN AN OPEN CHANNEL HAVING A TRIANGULAR CROSS-SECTION.
- (b) Laboratory project.
- (d) Basic research.
- (e) Data being obtained from a channel artificially roughened.
- (f) Investigation reactivated, additional data being taken with new improved instruments, one of which is a hot wire probe.
- (2536) STUDY OF HOMOLOGOUS TURBULENCE.
- (b) Laboratory project, formerly National Science Foundation.
- (d) Basic research.
- (e) The nature of turbulence (its production and dissipation) is being studied in the simplest possible shear flow-plane Couette flow where the shear is constant and the turbulence homogeneous but not isotropic. Mean-flow studies essentially complete.
- (f) Reactivated.
- (3427) STRUCTURE OF TURBULENCE NEAR ROUGH SURFACES.
- (b) Bureau of Ships Fundamental Hydromechanics Research Program.
- (d) Basic research; experimental.
- (e) Information on mean-flow and turbulence structure near roughnesses being studied in an 8-inch "natural roughness" pipe and in 3-inch sand-roughened pipe. Basic question is how roughness produces turbulence.
- (h) Report in preparation.
- (4142) TURBULENT BOUNDARY-LAYER FLOW TOWARDS A NORMAL STEP.
- (b) Laboratory project.
- (d) Basic research.
- (e) An analytical and experimental study is being made of upstream separation, i.e., the real fluid behavior (separation, mixing, reattachment) in front of a normal step projecting inward from a plate along which fluid is flowing with a turbulent boundary layer. Air is fluid medium being used.
- (f) Investigation in process.
- (g) First phase of study completed; in one case rather good agreement was found between theoretical solution and experimental observation of separation streamline.
- (h) "Separation of Turbulent Shear Flow Ahead of a Normal Step", by D. B. Taulbee, PhD Thesis, Univ. of Illinois, 1964.
- (4143) HEMODYNAMICS SIMILITUDE STUDY OF AN ARTERIAL DISTRIBUTION SYSTEM.
- (b) Public Health Service, National Institutes of Health, Research Grant No. HE08330-02.
- (c) Prof. M. E. Clark, 123 Talbot Laboratory, University of Illinois, Urbana, Illinois.
- (d) Basic research; experimental.
- (e) The flow of blood in the Circle of Willis--the arterial distribution system for the brain--is to be studied utilizing large-sized models. Present goal is to fabricate a model which will simulate in as many ways as possible the prototype and its flow.
- (f) Investigation in process.
- (g) Fabrication and model-prototype verification of first-stage model essentially complete. Studies being initiated in the pulsatile flow aspects.
- (4558) EFFECT OF TURBULENT NORMAL STRESS ON DRAG EVALUATION BY WAKE MOMENTUM METHOD.
- (b) Laboratory project.
- (d) Basic research.
- (e) Conventionally the evaluation of the drag of bodies from wake transverse ignores normal stresses in wake. Experimental measurements one half a chord length behind a fineness-ratio 3.5 strut indicates a contribution of some 2 percent. Further studies including finer bodies are planned.
- (f) Investigation in process.
- (4559) FLOW STABILITY AND HEAD LOSS IN BRANCHED TUBES.
- (b) Public Health Service, National Institute of Health, Research Grant No. HE08330-02.
- (c) Prof. M. E. Clark, 123 Talbot Laboratory, Univ. of Illinois, Urbana, Illinois.
- (d) Basic research; experimental.
- (e) In conjunction with a model study of the Circle of Willis--the arterial distribution system for the brain--a need was felt for a better understanding of the stability of viscous flows through certain types of junctions as well as the amount of head loss which occurs. A series of bifurcations and fusions of rigid, circular tubes are being studied to gain this understanding.
- (f) Investigation in process.
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- IOWA STATE UNIVERSITY, Department of Agricultural Engineering.
- Inquiries concerning the following projects should be

addressed to Dr. H. P. Johnson, Department of Agricultural Engineering, Iowa State University, Ames, Iowa.

(2330) DEPTH, SPACING AND HYDRAULICS OF TILE DRAINS.

- (b) Laboratory project.
- (d) Theoretical and field investigation; basic and applied research; master's and doctor's thesis.
- (e) Analytical and experimental approach is being studied to determine depth and spacing of tiled drains by analyzing soil characteristics and geometry of systems. Work is cooperative with Dr. Kirkham, Soil Physics Department of Agronomy. Studies of the relationship of hydrologic and applied hydraulic problems of field tile systems being made.
- (g) Studies of models and mathematical theory of unsteady flow through porous media are being conducted in the Department of Agronomy under the direction of Dr. Kirkham. A field study of flow through the spacing between individual tile for saturated conditions has been completed. A study relating the needed tile depth and spacing to conditions described by the water balance for given conditions is being conducted in the Agricultural Engineering Department.
- (h) "The Falling Water Table Between Open Ditch Drains," by J. T. Ligon, Don Kirkham and H. P. Johnson, Soil Science, 97:113-118. 1964.
"Solving Tile Drainage Problems by Using Model Data", by B. L. Grover and Don Kirkham. Research Bulletin 523, Agricultural and Home Economics Experiment Station, Iowa State Univ., Ames, Iowa. 1964.

(2331) SURFACE RUNOFF FROM AGRICULTURAL WATERSHEDS.

- (b) Laboratory project.
- (d) Theoretical; applied research; master's thesis.
- (e) A study relating volumes and rates of runoff from gaged watersheds to volumes and rates of runoff obtained by synthetic methods is in progress.

(2333) IMPROVEMENT OF SURFACE DRAINS WITH TILE BLIND INLETS.

- (b) Laboratory project.
- (d) Field investigation; design.
- (e) Field study is being continued to determine the effect of different tile backfill material on the flow of water into the tile drains.
- (f) Completed.

(2334) RUNOFF FROM SMALL WATERSHEDS.

- (b) Laboratory project.
- (d) Field investigation; applied research; design.
- (e) Measurements of rainfall, surface runoff, soil moisture, water table levels, and evaporation being made on six small agricultural watersheds under a single cover crop. Five additional agricultural watersheds are being gaged for rainfall and surface runoff.

(4150) COMPARISON OF SYNTHETIC UNIT GRAPH METHODS.

- (b) Laboratory project.
- (d) Experimental, applied research.
- (e) Three synthetic unit graph methods developed for application to small watersheds were compared with actual unit graphs from given watersheds.
- (f) Completed.
- (g) The study indicated that large errors in predicted peak discharge for given storms may result from use of synthetic unit graphs.

(4913) QUANTITATIVE EVALUATION OF GULLY EROSION.

- (b) Laboratory project.
- (d) Field investigation; applied research.
- (e) Multiple regression has been used to relate gully growth to a series of independent variables. Initial equation was developed from 20 year history on one watershed. Study has expanded to include two watersheds with continuing measurement of gully growth, rainfall, runoff, and sediment production.
- (h) "Factors in Gully Growth in the Deep Loess Area of Western Iowa", by C. E. Beer and H. P. Johnson. Transactions of ASAE, 6:237-240. 1963.

(5370) RELATIONSHIP OF WATERSHED CHARACTERISTICS TO RUNOFF.

- (b) Laboratory project.
- (d) Theoretical and field investigation; basic and applied research; master's and doctor's thesis.
- (e) Available field data from several sources are being used to relate such characteristics as rainfall, watershed cover, soil, and watershed geometry to water yields and storm runoff characteristics.
- (h) "Regional Flood Frequency Determination in Iowa", by R. E. Hermanson. M.S. Thesis submitted to Iowa State University Library, 1964.

IOWA STATE UNIVERSITY, Department of Agronomy.

(3079) MOVEMENT OF WATER IN SOILS.

- (b) Laboratory project.
- (c) Dr. Don Kirkham, Department of Agronomy, Iowa State University. 50010
- (d) Theoretical and applied research; Doctor's thesis.
- (e) Theoretical work done on the movement of ground water in soil, particularly in the saturated phase continues. Mr. John C. Corey is continuing isotope work on water movement in the unsaturated state (miscible displacement) in cooperation with the Iowa State University Institute for Atomic Research.
- (h) "Some Physical Processes Causing Movement of Ions and Other Matter Through Soil," Don Kirkham. Mededelingen Van De Landbouwhogeschool En De Opzoekingsstations Van De Staat Gent. DEEL XXIX Nv. 1 pp. 21-43, 1964.
"The Streamline Function for Axially Symmetric Ground Water Movement," Dan Zaslavsky and Don Kirkham. Soil Sci. Soc. Amer. Proc. 28:150-164. 1964.
"Miscible Displacement of Tagged Nitrogen and Phosphorus in Saturated and Unsaturated Porous Material," John C. Corey. Progress report for AEC, Contract AT(11-1)-1269, Feb. 1964. Available from the Dept. of Agronomy, Iowa State University, Ames, Iowa.

(4592) MOVEMENT OF WATER FROM WASTE RECHARGE INSTALLATIONS.

- (b) U. S. Department of Health, Education, and Welfare, Public Health Service, National Institute of Health.
- (c) Dr. Don Kirkham, Department of Agronomy, Iowa State Univ., Ames, Iowa 50010.
- (d) Theoretical and field investigation; basic and applied research; master's and doctor's thesis.
- (e) The purpose of this project is to discover laws which predict, from the geometry of the waste recharge installation, and from the physical properties of the soil about it, how fast, and how far at certain times, water will move from the installation. This will be accomplished by (1) obtaining empirical laws governing seepage of water from an idealized scaled model (2) testing by full-scale field experiments to see if the empirical laws found in (1) above need to be

modified when applied to field conditions, and (3) formulating rational relations between the water movement, the geometry of the system and the soil conditions, by setting up and solving the appropriate seepage differential equations and checking the result against the experimental data from (1) and (2) above.

- (h) "Theory of Soil Water Seepage Near Tile Drains for a Curved Water Table," Arthur W. Warrick. Thesis for the degree of Master of Science, Iowa State Univ. Library, Ames, Iowa 1964.
- "Physical Artifices and Formulas for Approximating Water Table Fall in Tile-Drained Land," Don Kirkham. Soil Sci. Soc. Proc. (in press) 1964.
- "Exact Theory for the Shape of the Free Water Surface About a Well in a Semi-Confined Aquifer," Don Kirkham. J. Geophysical Res. 69: 2537-2549, 1964.

IOWA INSTITUTE OF HYDRAULIC RESEARCH, University of Iowa.

- (66) HYDROLOGIC STUDIES, RALSTON CREEK WATERSHED.
 - (b) Cooperative with the Agricultural Research Service and the U.S. Geological Survey.
 - (c) Prof. J. W. Howe, Department of Mechanics and Hydraulics, University of Iowa, Iowa City, Iowa.
 - (d) Field investigation; applied research, and M. S. theses.
 - (e) Study being made of relation between rainfall and runoff over a small area. Discharge from a 3-square-mile area measured by U. S. G. S.; rainfall records at five automatic recording stations collected by Agricultural Research Service. Continuous records since 1924 of precipitation, runoff, groundwater levels, and vegetal cover.
 - (g) Yearly records available for examination at Iowa Institute of Hydraulic Research.
 - (h) Reports prepared annually since 1924 available in files at the Iowa Institute of Hydraulic Research. Summary of 33-year record published as Bulletin 16 of the Iowa Highway Research Board in 1961; available upon request from Iowa Highway Commission, Ames, Iowa.
- (67) COOPERATIVE SURFACE-WATER INVESTIGATIONS IN IOWA.
 - (b) Cooperative with U. S. Geological Survey.
 - (c) District Engineer, U. S. Geological Survey, Iowa City, Iowa.
 - (d) Field investigation; collection of basic stream-flow data.
 - (e) Stream-flow and sediment measuring stations maintained throughout the State of Iowa cooperatively on a continuous basis. Records collected by standard methods of U. S. G. S.
 - (g) Records of stream-flow and sediment discharge computed yearly.
 - (h) Records contained in Water-Supply Papers available through offices of the Geological Survey.
- (68) HYDROLOGIC STUDIES, RAPID CREEK WATERSHED.
 - (b) Cooperative with U. S. Geological Survey.
 - (c) District Engineer, U. S. Geological Survey, Iowa City, Iowa.
 - (d) Field investigation; applied research.
 - (e) Study being made of relation between rainfall and runoff over a small area. Discharge from a 25-square-mile area measured and flood runoff on main subbasins determined by U. S. Geological Survey; rainfall records at four automatic recording stations collected by U. S. Weather Bureau. Continuous records since 1941 of precipitation, runoff, and ground-water levels.
 - (g) Rainfall records published in Weather Bureau Climatological Bulletins and surface runoff and ground-water levels published in Geological

Survey Water-Supply Papers.

- (73) MEASUREMENT OF TURBULENCE IN FLOWING WATER.
 - (b) Cooperative with Office of Naval Research, Department of the Navy.
 - (c) Dr. Philip G. Hubbard, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental and theoretical; basic and applied research.
 - (e) Instruments, primarily electrical in operation, are being developed to measure the characteristics of turbulent flow over a wide range of laboratory and field conditions. Both sensing and computing elements are involved.
 - (g) Investigation of the salinity factor has shown that the theoretical heat dissipation (Kramer's Law) is encountered for mineral oil, distilled water, and salinity up to that of tap water (approx. 3×10^{-4} ohm-cm). Increasing salinity reduces the heat transfer, so that at a conductivity of 11.1×10^{-4} ohm-cm the heat transfer is only 60% of the theoretical value. Suspended solids down to the wire diameter (18 microns) must be removed for stable operation.
 - (h) "Heat Transfer from Fine Wires in Flowing Liquids" Kuo, A. Y.-S., M.S. Thesis, Univ. of Iowa, Jan. 1965. (Available on loan).
- (79) CAVITATION.
 - (b) Cooperative with Office of Naval Research, Department of the Navy.
 - (c) Dr. Hunter Rouse, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental and theoretical; basic research and graduate theses.
 - (e) Basic information is sought on cavitation for systematically varied boundary conditions. Studies of cavitation in abrupt conduit expansions are now being pursued.
- (1875) CHARACTERISTICS OF STABLE EDDIES.
 - (b) Laboratory project, partially supported by Office of Naval Research, Department of the Navy and U. S. Army Research Office (Durham).
 - (c) Dr. Hunter Rouse, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental and analytical; basic research.
 - (e) Distributions of velocity, pressure, and turbulence are being investigated throughout the vicinity of separation zones produced by abrupt changes in flow section, to the end of establishing the primary eddy characteristics as functions of the boundary geometry.
 - (g) Studies are being conducted on flow in the wakes of conical after-bodies. Analytical evaluations are also being carried out for a two-dimensional and an axisymmetric boundary expansion.
- (2091) RESEARCH ON SHIP THEORY.
 - (b) Cooperative with Office of Naval Research and David Taylor Model Basin, Department of the Navy.
 - (c) Dr. Louis Landweber, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental and theoretical; basic research.
 - (e) To determine the laws governing the forces, moments, and motions of ships. Work is under way on the following problems:
 - (1) Development of procedure for computing potential flow about ship forms.
 - (2) Determination of hydrodynamic images, forces, and moments for a spheroid in an arbitrary potential flow.
 - (3) Effect of tank size on ship-model resistance.
 - (4) Resolution of viscous and wave drag by means of wake and surface-profile measurements.
 - (5) Effect of a free surface on separation.
 - (6) Vibration of ships.
 - (h) "Force on a Prolate Spheroid in an Axisymmetric Potential Flow," by L. Landweber and M. Macagno, Journal of Ship Research, vol. 8, No. 1, June 1964.
 - "Added Masses of Vibrating Elastic Bodies," by R. G. Warnock, IIHR Report, Feb. 1964.

- "Vibration of a Flexible Cylinder in a Fluid," by L. Landweber, IIHR Report, August 1964.
- "Drag of an Oscillating Plate in a Stream," by M. Tseng, M. S. Thesis, Univ. of Iowa, Jan. 1965. (Available on loan).
- (2328) INVESTIGATION OF SURFACE ROUGHNESS.
- (b) Cooperative with U. S. Geological Survey, Office of Naval Research, and Waterways Experiment Station.
 - (c) Dr. Hunter Rouse, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental; basic research for doctoral dissertation.
 - (e) Apparatus for measuring drag on individual roughness elements and element groups is now in use.
 - (h) "Some Roughness-Concentration Effects on Boundary Resistance" by E. M. O'Loughlin and E. G. Macdonald, submitted to La Houille Blanche. "A Critical Analysis of Open-Channel Resistance" by Hunter Rouse, submitted to ASCE Journal of the Hydraulics Division.
- (2541) DEVELOPMENT OF INSTRUMENTS FOR USE IN ANALYZING APERIODIC SIGNALS.
- (b) Cooperative with Office of Naval Research, Department of the Navy.
 - (c) Dr. Philip G. Hubbard, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental; applied research.
 - (e) The purpose is to improve the analysis of turbulent velocity and pressure fluctuations, especially where long-period fluctuations are significant.
 - (g) An improved analog-to-frequency type of integrator has been completed and is in use for regular laboratory research. An intermittency circuit sensitive to instantaneous amplitude is under development, and spectrum measurements are being given consideration. The use of silicon semiconductors for non-linear applications is under active investigation.
- (3074) WAKE OF ZERO MOMENTUM FLUX.
- (b) Cooperative with Office of Naval Research, Department of the Navy.
 - (c) Dr. Eduard Naudascher, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental; basic research.
 - (e) Mean flow and turbulence characteristics are being measured and the energy transformation is being analyzed in the field of flow past a bluff, axisymmetric body with a centrally located jet for the particular condition of zero momentum flux.
 - (g) Radial distributions of mean-flow and turbulence characteristics exhibit a more complex form of self-preservation than is common to free-turbulence flows. The axial variation of flow characteristics is described by a logarithmic rather than by a power law. An analogous replacement of power laws by one logarithmic relationship proves successful also for decaying homogeneous turbulence.
 - (h) "Flow in the Wake of a Self-Propelled Body and Related Sources of Turbulence," by E. Naudascher, Iowa Inst. of Hydraulic Research Report, Nov. 1964. (To be submitted to the Journal of Fluid Mechanics).
- (3428) MECHANICS OF BANK SEEPAGE IN NATURAL STREAMS DURING FLOOD FLOWS.
- (b) Laboratory project in cooperation with U. S. Geological Survey.
 - (c) Prof. J. W. Howe, Dept. of Mechanics and Hydraulics, University of Iowa, Iowa City, Iowa.
 - (d) Field investigation; basic research for Ph. D. thesis.
 - (e) Observations taken on transverse profile of ground-water levels during rise and recession of hydrographs. Sections on Missouri, Des Moines, Boone, Iowa, and English Rivers, Clear Creek and Rapid Creek. Permeability tests made by pumping wells.
- (f) Continuing.
- (g) Early results indicate substantial flow into banks during period of rise, thus showing a negative groundwater contribution to the flow in this period.
- (3432) ACCELERATED MOTION OF A SPHERE FALLING IN AN OSCILLATING FLUID.
- (b) Laboratory project.
 - (c) Mr. E. M. O'Loughlin, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental and analytical; basic research and Ph. D. dissertation.
 - (e) To determine accelerated motion of a sphere falling in an oscillating fluid.
 - (f) Completed.
 - (h) "Accelerated Motion of a Sphere in a Viscous Fluid," by Lucien M. Brush, Jr., Han-Wong Ho, and Ben-Chie Yen, ASCE Journal of the Hydraulics Division, vol. 90, No. HY 1, Jan. 1964.
- (3738) SEDIMENT DIFFUSION.
- (b) Laboratory project partially supported by a grant from Gulf Research and Development Co.
 - (c) Mr. E. M. O'Loughlin, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Experimental; Ph. D. dissertation.
 - (e) To determine the sediment-diffusion characteristics for small concentrations of particles in a submerged jet of water.
 - (f) Completed.
 - (h) "Diffusion of Sediment in a Submerged Jet," by Surya Rao Singamsetti, Ph.D. Dissertation, Univ. of Iowa, Feb. 1965. (Available on loan).
- (3739) EDUCATIONAL FILMS ON THE MECHANICS OF FLUIDS.
- (b) National Science Foundation.
 - (c) Dr. Hunter Rouse, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (e) Six 20-minute sound films in color are planned to cover following material: (1) An introduction to the subject, stressing its great breadth of coverage, the necessarily close tie between theory and experiment, the role of the scale model in engineering analysis and design, and methods of flow measurement in laboratory and field. (2) The source and significance of the fundamental principles of continuity, momentum, and energy, and their application to typical problems in many professional fields. (3) Gravitational phenomena, including jets, nappes, channel transitions, waves, surges, and effects of density stratification. (4) Effects of viscosity, examples of laminar flow, characteristics of fluid turbulence, and problems of surface resistance. (5) Form drag and lift, and their application to propulsion and fluid machinery. (6) Compressibility effects - water hammer, submarine signaling, gravity-wave and sound-wave analogies, and supersonic drag.
 - (g) First four films of series, "Introduction to the Study of Fluid Motion," "Fundamental Principles of Flow," "Flow in a Gravitational Field," and "Characteristics of Laminar and Turbulent Flow" now available from Audiovisual Center, University of Iowa, Iowa City, Iowa. Fifth film "Form Drag, Lift, and Propulsion" in preparation.
- (3740) HYDRODYNAMICS OF FLUIDS UNDER CONDITIONS OF RAPID ACCELERATION.
- (b) Rock Island Arsenal, U. S. Army.
 - (c) Dr. Philip G. Hubbard, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
 - (d) Theoretical and experimental; basic research.
 - (e) Analytical techniques which are applicable to systems involving rapid acceleration of fluids through constructions or of solids through fluids. Results will be expressed as lumped-constant parameters similar to

- those used for steady-flow phenomena.
- (g) Field tests have shown that errors are reduced by an order of magnitude if the volume changes due to compressibility are considered. As shown by analysis of simplified model, pressure waves may also require consideration in the presence of extremely short impulses.
- (4145) INTERFACIAL EFFECTS IN FLUID FLOW WITH DENSITY STRATIFICATION.
- (b) Cooperative with U. S. Army Research Office (Durham).
- (c) Dr. Enzo O. Macagno, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
- (d) Experimental; basic research and graduate theses.
- (e) Instability and mixing of two fluid layers of different densities flowing in the same direction. Effect of stratification on turbulent mixing of two fluid layers.
- (g) Experiments with an agitation unit to determine intereffects of turbulence and stratification continue. A small unit has been set up and is being used for exploratory studies of effects of curvilinearity on stratified flow. An electrical probe for direct measuring and recording of saline concentration has been developed and is now being tested under variable conditions of density stratification.
- (h) "The Stability of Stratified Flow on Nearly Vertical Slopes," by W. M. Sangster, Ph.D. Dissertation, Univ. of Iowa, June 1964. (Available on loan).
- "Estuarine Salt Wedges," by J. B. Hinwood, The Dock and Harbour Authority, Vol. 45, n. 525, p. 79-83, July 1964.
- "Instabilité dans la zone d'établissement d'un courant avec stratification de densité," by E. O. Macagno and J. B. Hinwood, Semes Journées de l'Hydraulique, Question I, Rapport I, Lille 1964. (English version available on request).
- Discussion, by J. B. Hinwood, of "Sediment Transportation Mechanics: Density Currents" by the Task Committee on Preparation of Sedimentation Manual, ASCE Journal of the Hydraulics Division, Vol. 90, No. 4, July 1964.
- (4148) MEAN-FLOW AND TURBULENCE CHARACTERISTICS OF RIVER BENDS.
- (b) Supported by the National Science Foundation.
- (c) Mr. E. M. O'Loughlin, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
- (d) Experimental; basic research; Ph.D. dissertation and M.S. thesis.
- (e) To determine the mean-flow and turbulence characteristics of flow in a model river bend.
- (g) The loss coefficient has been determined as a function of the Froude number and width-depth ratio for the channel being studied. Flow dissimilarities between air and water models have been observed. Longitudinal and transverse velocity, bed shear, turbulent shear, and surface elevation have been measured for a trapezoidal channel at various Froude numbers and width-depth ratios.
- (h) "Air-Tunnel Study of a Meander Model," by H. Tieleman, M. S. Thesis, Univ. of Iowa, Feb. 1964. (Available on loan).
- "The Variation of Loss Coefficient with Froude Number in an Open-Channel Bend" by Sikandar Hayat, M.S. Thesis, Univ. of Iowa, Jan. 1965. (Available on loan).
- (4149) DRAG OF SUPERCAVITATING BODIES OF REVOLUTION.
- (b) Bureau of Ships, Office of Naval Research.
- (c) Dr. Louis Landweber, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
- (d) Theoretical; applied research.
- (e) An approximate method of computing pressure distributions on supercavitating bodies of revolution has been developed. Equipment for measuring drag of nose forms with air-simulated supercavitating flow in a towing tank has been constructed and experiments are under way.
- (h) "A Preliminary Study of the Effect of the Free Surface on the Drag of a Truncated 2:1 Ellipsoid," by A. D. Newsham, IHR Report, Aug. 1964.
- (4973) EFFECT OF RADIUS OF CURVATURE ON LOSS IN 90-DEGREE TRAPEZOIDAL BEND.
- (b) Laboratory project.
- (c) Prof. J. W. Howe, Dept. of Mech. & Hydr., Univ. of Iowa, Iowa City, Iowa.
- (d) Experimental; for M.S. thesis.
- (e) Observation of series of bends with varying ratios of radius to width.
- (f) Completed.
- (g) Loss due to bend is a minimum at r/w ratio of 4. However, if one considers the total loss between fixed points on the tangents, the largest radius gives the least loss.
- (h) "Effect of Radius of Curvature Upon Loss in a Trapezoidal Equiradial 90° Open Channel Bend at Constant Slope," by Sie Ling Chiang, M. S. Thesis, Univ. of Iowa, Jan. 1964. (Available on loan).
- (4974) TURBULENCE CHARACTERISTICS OF THE WAKE OF A BODY OF REVOLUTION.
- (b) Cooperative with David Taylor Model Basin, Dept. of the Navy.
- (c) Dr. Philip G. Hubbard, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
- (d) Experimental basic research.
- (e) Measurements are being made of the turbulence near the stern of an ellipsoid mounted in an air tunnel. Specially designed instruments are used to respond correctly to the low-frequency, high-intensity components.
- (g) Data on the pressure, velocity, and components of turbulence are at hand for a zero angle of attack.
- (h) "An Experimental Study of the Turbulence in the Wake of a Body of Revolution" by P. J. L. Gear, M.S. Thesis, Univ. of Iowa, Jan. 1965. (Available on loan).
- (4975) EFFECT OF GATE SLOTS UPON DOWNPULL.
- (b) Cooperative with Tennessee Valley Authority.
- (c) Dr. Eduard Naudascher, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
- (d) Experimental; applied research.
- (e) The pressure distribution on the lip of a high-head gate is being measured for various gate-slot geometries. A parameter is to be evaluated for the effect of the gate slot on the hydraulic downpull.
- (f) Completed.
- (h) "Effect of Gate Slots upon the Hydrodynamic Forces Acting on High-Head Gates," by N. Gillissen, M.S. Thesis, Univ. of Iowa, Jan. 1965. (Available on loan).
- Discussion by N. Gillissen and C. Quevedo of "Hydrodynamic Analysis for High-Head Leaf Gates," by E. Naudascher, H. E. Kobus, and R. P. R. Rao, ASCE Journal of the Hydraulics Div., Vol. 90, No. HY 3, May 1964.
- (4976) EFFECT OF LIFTING BEAMS ON GATE VIBRATION.
- (b) Cooperative with Tennessee Valley Authority.
- (c) Dr. Eduard Naudascher, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
- (d) Experimental; applied research.
- (e) The effect of the lifting-beam geometry upon the fluctuating hydrodynamic force acting on a multiple-leaf gate during overflow and underflow is being investigated.
- (h) Discussion by E. Naudascher and C. Farrell of "Form-Induced Hydrodynamic Forces on Three-Leaf Intake Gates," by R. A. Elder and T. M. Garrison, ASCE Journal of the Hydraulics Division, Vol. 90, HY 3, May 1964.
- (5319) HEAD LOSS IN TRAPEZOIDAL CHANNEL BENDS HAVING VARIOUS DEFLECTION ANGLES.
- (b) Laboratory project.

- (c) Prof. J. W. Howe, Dept. of Mechanics and Hydraulics, Univ. of Iowa, Iowa City, Iowa.
- (d) Experimental; for M.S. Thesis.
- (e) Evaluation of loss coefficient in equiradial trapezoidal bends having various deflection angles.

(5320) DISCHARGE COEFFICIENTS OF SKEWED PIPE ORIFICES.

- (b) Laboratory project.
- (c) Prof. J. W. Howe, Dept. of Mechanics and Hydraulics, Univ. of Iowa, Iowa City, Iowa.
- (d) Experimental; for M.S. Thesis.
- (e) Effect of inclination of orifice plate to pipe centerline for orifices of the same projected diameter.

(5321) PRESSURE FLUCTUATIONS AT GATES OUTLET WORKS.

- (b) Cooperative with U. S. Army Corps of Engrs.
- (c) Dr. Eduard Naudascher, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
- (d) Experimental, basic research.
- (e) Effects of shear-layer instability on the spectral distribution and the intensity of pressure fluctuations that may induce gate vibrations are being investigated for various gate and conduit geometries.

THE JOHNS HOPKINS UNIVERSITY, Applied Physics Lab.

(2335) APPLICATION OF SWITCHING TECHNIQUES TO HYDRAULIC CONTROL SYSTEMS.

- (b) Bureau of Weapons, Department of the Navy.
- (d) Theoretical and experimental; applied development and design.
- (e) Study the dynamic qualities of an acceleration switching hydraulic servomechanism while operating in a closed loop under the presence of various loads and environmental conditions on the transfer valve, actuator and feedback transducer.
- (g) The operation of a broad bandpass servo-mechanism driving a low resonant frequency linkage has resulted in radial design compromises to prevent instability. Extension of acceleration switching techniques without any mechanical modifications has permitted closed loop operation with bandpasses equal to or exceeding the linkage characteristics.
- (h) "Design of a Hydraulic Servo with Improved Bandpass Characteristics When Driving a Resonant Mechanical Load," APL/JHU CM-962, by W. Seamone.

(3436) ADAPTIVE ELECTRO HYDRAULIC SERVOMECHANISMS.

- (b) Bureau of Weapons, Department of the Navy.
- (d) Theoretical and experimental.
- (e) Techniques have been developed for designing linear servomechanisms with a limit cycle instability about a relay type non-linearity. The closed loop characteristics of this servomechanism becomes invariant to any pure gain changes occurring in the linear elements. This servomechanism, categorized as a self-oscillating control servomechanism, appeared to be an evolutionary improvement over the acceleration switching hydraulic servomechanism.
- (g) A self-oscillating rate servomechanism has been operated with the loop closed around the valve spool position. Predictable self-oscillation frequency was achieved and dynamic performance bandpass was independent of hydraulic supply pressure between 500 and 2000 psi. The bandpass of both servomechanisms exceeded 60 cycles per second with the latter operating a complex mechanical load system.

THE JOHNS HOPKINS UNIVERSITY, Department of Sanitary Engineering and Water Resources, School of Engrg.

Inquiries concerning the following projects should be addressed to Dr. John C. Geyer, Chairman, Dept. of Sanitary Engineering and Water Resources, The Johns Hopkins University, Baltimore, Maryland 21218

(856) HYDROLOGY OF STORM DRAINAGE SYSTEMS IN URBAN AREAS.

- (b) Baltimore City, Baltimore County, Maryland State Roads Commission, and the U. S. Bureau of Public Roads.
- (d) Field investigation; basic research and design.
- (e) Study of rainfall and runoff relationships as affected by various drainage area parameters. At present, runoff from 6 urban areas ranging in size from 10 to 150 acres are gaged, 5 by stage instruments and 3 by Parshall Flumes. Three recording systems which simultaneously record rainfall and runoff from 12 inlet areas provide good opportunity for detailed study. About 10 years of rainfall records now exist for a network of 12 recording gages covering an area of 50 square miles.
- (g) The Rational Method of storm drainage design has been studied to see if the method could be verified or improvements in its use suggested. An attempt was made to study the assumption, implicit in the method, that the frequency of occurrence of the computed design peak runoff rate is the same as the frequency of occurrence of the selected rainfall intensity. The results suggest that constant values of the "C-Factor" and "time of concentration" can be selected for small urban areas such that this assumption is approximately correct for the range of rainfall intensities commonly considered in design practice in the Baltimore area.
- (h) Technical Report No. 1, John C. Schaake, Jr., Dept. of Sanitary Engineering and Water Resources, The Johns Hopkins University, Baltimore, Maryland, 21218.

(3437) RESIDENTIAL WATER USE RESEARCH PROJECT.

- (b) Federal Housing Administration and 16 participating Water Utilities.
- (d) Field investigation; applied research and design.
- (e) This project is directed toward obtaining data on maximum hourly demands and water use patterns in residential areas having varying populations and located in various climatic regions throughout the country. It also is directed toward obtaining information on the effect of lawn sprinkling and other large water uses on maximum demands. The purpose of the project is to obtain a rational design criteria for water distribution systems, to provide a basis for evaluating water rate structures and a basis for improving system operation.
- (g) Forty areas of subdivision size were selected so that water is supplied to each area through a single main with a compound meter-punched tape recorder. Areas were selected to represent major climatic regions of the country; and to represent varying economic levels, lot sizes, water rate structures, and other factors that influence water use. Some comments can be made about data collected during the summer of 1963. The magnitude of peak hourly demands in the west are about the same as those in the east for metered residential areas similar in character. Peak demands in metered areas are apparently correlated more with lot size than with climatic location. The ratios of peak to average use are lower in the west than in the east because average annual use is higher in the west where the sprinkling season is longer. Peak demands for unmetered areas are almost double those for metered areas. During the non-sprinkling season when all water is used for domestic purposes, variation from metered areas to unmetered areas is small.

Population density appears to be the factor with the greatest influence on domestic use. Weather conditions, proportion of consumers metered, and lot size appear to be the factors with the greatest influence on sprinkling use.

- (h) "Progress Report on the Residential Water Use Research Project," by F. P. Linaweaver, Jr., John C. Geyer, and Jerome B. Wolff, Journal American Water Works Association, Volume 56:1121 (Sept., 1964).
"Report I on Phase Two of the Residential Water Use Research Project," F. P. Linaweaver, Jr., and Jerome B. Wolff, Dept. of Sanitary Engineering and Water Resources, The Johns Hopkins Univ., 30 pages, (May, 1964). A limited number of copies are available upon request.

(3438) RESIDENTIAL SEWERAGE RESEARCH PROJECT.

- (b) Federal Housing Administration.
- (d) Field investigation; operation and design.
- (e) Examination of adequacy and utility of residential sewerage system design criteria. Determination of the effects of parameters of design, construction, loading, and natural phenomena on operation of sewerage systems. Research includes analysis and study of representative sewerage systems throughout the country.
- (f) Completed.
- (g) General problems facing sewer designers have been studied using field data collected in four U. S. communities. Analysis of these data indicates that basic causes of maintenance difficulties are tree roots, accumulations of debris in the absence of roots, other causes, and in areas having cohesionless sub-soil, sewer cave-ins. Proportionately fewer blockages occur when grades are moderate, and proportionately more occur at the upper terminals of the sewers. In eight-inch pipe, manhole spacing has little effect on the labor costs of stoppage relief. Emphasis is placed on statistical techniques for estimating domestic sewage flow. Flow of rainwater and groundwater was at times found to be excessive in all systems studied. Limited data on costs of operating and maintaining sewage pumping stations are reported and evaluated.
- (h) "An Evaluation of the Problems of Sanitary Sewer System Design," by John C. Geyer and John J. Lentz, Federal Housing Administration, Technical Studies Publication FHA No. 564, Washington, D. C., 20411, Sept., 1964.

(5171) GROUND WATER STORAGE PROJECT.

- (b) National Institutes of Health Research Grant.
- (d) Field investigation, applied research.
- (e) Application of gravity meter to study of change of storage of ground water in water budget of 38 acre drainage basin.
- (g) Commencing collection of data.

UNIVERSITY OF KANSAS, Dept. of Mechanics and Aerospace Engineering.

Inquiries concerning the following projects should be addressed to Dr. Y. S. Yu, Dept of Mechanics and Aerospace Engineering, Univ. of Kansas, Lawrence, Kansas 66045.

(3743) STUDY OF THE MECHANICS OF DIVIDED FLOW.

- (b) National Science Foundation.
- (d) Theoretical and experimental; basic research.
- (e) A study of the instability of flow at branches of a manifold and of flow into a slot in a plane wall of a semi-infinite flow.
- (f) Completed.
- (h) "Free Streamline Analysis of Flow from Nozzles, Flow Through Side Inlets, and Flow Past Corners," by David W. Appel and Y. S. Yu, Studies in Engineering Mechanics, Report No. 17, 1963. (Available upon request.)

(3745) BASIC CHARACTERISTICS OF AN OVERLAND FLOW.

- (b) Waterways Experiment Station, Corps of Engineers, U. S. Dept. of the Army.
- (d) Theoretical; basic research.
- (e) Data from experiments made by the Los Angeles District, Corps of Engineers, on the controlled surface runoff due to rainfall on an impervious plane slope are analyzed. The objective is to provide an improved method for estimating overland flow in the drainage of airfield and expressways.
- (f) Completed.
- (g) The analysis was extended to runoff on an impervious surface due to rainfall of step function. The anomalous increase in discharge which often followed the cessation of rain is shown as a consequence of turbulent flow becoming laminar when the battering of the rain ceases.
- (h) "Runoff from Impervious Surfaces," by Y. S. Yu and John S. McDown, IAHR, Journal of Hydraulic Research, Vol. 2, No. 1, 1964.

(4151) SEPARATION OF FLOW AT INTERIOR CORNERS.

- (b) Kimberly-Clark Corporation, Neenah, Wis.
- (d) Theoretical and experimental; basic research.
- (e) The separation of laminar flow at interior corners is studied to determine experimentally and mathematically the flow pattern and the geometry of the zone of separation.
- (h) "The Study of Separation of Flow at Interior Corners--Progress Report," by D. W. Appel and Y. S. Yu, 1964.

(4641) HYDRODYNAMIC STABILITY OF FLOW BETWEEN TWO CONCENTRIC ROTATING CYLINDERS.

- (b) Laboratory project.
- (d) Theoretical; basic research for M. S. thesis.
- (e) Mathematical solution of Taylor's problem for finite radii of the concentric cylinders is sought.
- (f) Completed.
- (h) "Stability of A Viscous Flow Between Two Rotating Coaxial Cylinders," by Y. S. Yu and Tah-Chen Sun, Journal of the Franklin Institute, Vol. 277, No. 2 February 1964.

(4643) MECHANICS OF BLOOD FLOW.

- (b) Laboratory project financed by the NASA grant to the University of Kansas.
- (d) Theoretical and experimental; basic research.
- (e) A study of flow problems pertaining to blood circulating in a vascular system.
- (g) An experimental study of the oscillating motion of air in a rigid, circular tube was performed to determine the velocity profiles for the laminar flow and to study the instability of the flow. Velocity profiles were measured with a constant-temperature hot-wire anemometer for various frequencies of oscillation with and without mean flow through the tube. Experiments were also performed to observe visually the stability of the flow. The measured velocity profiles were compared with known analytical results. The instability of the flow was also discussed.
- (h) "An Experimental Investigation of Oscillating Flow in a Tube," by Charles C. Bailey, M. S. Thesis, 1964. (Available on loan at the Engineering Library, The University of Kansas.)

(4944) SOLUTION OF POTENTIAL FLOW WITH FREE STREAMLINES BY INTEGRAL EQUATION METHOD.

- (b) University research grant.
- (d) Theoretical; M.S. thesis.
- (e) To develop a method to solve free-streamline problems with curved walls and without gravity and flows with straight walls with gravity.
- (g) A method has been developed for calculating the pressure distribution and free-surface profile of a steady, two-dimensional, potential flow past a spillway bucket or a toe-curve without gravity. The method has been

applied to compute the pressure distributions on two spillway buckets of the Hartwell Dam with a 30-ft radius and lip angles of 20 degrees and 40 degrees, respectively. The computed results agree well with measurements made by Waterways Experiment Station.

- (h) "Pressure Distributions on Spillway Flip Buckets," by Tio-Chun Chen and Y. S. Yu (to appear in ASCE Journal of Hydraulics Division).

(4945) SECONDARY MOTIONS IN A "DRAIN-HOLE" VORTEX.

- (b) Laboratory project.
- (d) Theoretical and experimental basic research for doctoral thesis.
- (e) The secondary motions in a steady "drain-hole" vortex flow are being studied to determine the mechanics of its formation and the effects of rotational speed of the tank and the water depth on the secondary motions.

(5290) A STUDY OF PRESSURE PULSATIIONS DUE TO CAVITATION IN FLOW THROUGH ABRUPT EXPANSIONS.

- (b) Tennessee Valley Authority.
- (c) Experimental and theoretical study for doctoral dissertation.
- (e) The main purpose of this study is to investigate the formation of cavitation pockets and the associated pressure fluctuations downstream from an abrupt expansion. Pressure pulsations will be measured for different flow rates, expansion ratios, and expansion geometry.

LEHIGH UNIVERSITY, Department of Civil Engineering.

Inquiries concerning the following projects and requests for reprints and technical reports should be addressed to Dr. J. B. Herbach, Associate Professor, Chairman, Hydraulics Div., Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pennsylvania 18015.

(2543) STUDY OF CONDUIT EXIT PORTALS.

- (b) Laboratory Project.
- (d) Experimental: M. S. Thesis.
- (f) General pressure-distribution study completed.
- (g) Tests of square and circular conduit with free-jet, horizontal apron, and three different wall flares, have been completed.

(3084) STUDY ON IMPROVING DESIGN OF A HOPPER DREDGE PUMP.

- (b) District Engineer, U.S. Army Engineer Dist., Marine Division, Philadelphia, Corps of Engineers.
- (d) Applied and Basic Research.
- (e) The immediate purpose of the study is to improve design of a hopper dredge centrifugal pump for pumping silt-clay water mixtures. The long-term objective is to determine the effect of Bingham Body-type of fluid on pumping characteristics. The project has been divided into four phases: (1) Model test of existing dredge pump; (2) recommendations for design changes of the dredge pump; (3) model investigation of the modified design of the dredge pump; and (4) analysis of the investigation and final recommendations. Phase 1 involved installation in the hydraulic laboratory of a 1:8 scale model of the dredge pump now used on the U.S. Corps of Engineers dredge ESSAYONS. Water as well as silt-clay-water mixtures (Bingham Body-type of fluid) were pumped and complete characteristics of the pump obtained for capacity of 0 to 1200 gallons per minute, speed of 1150 to 1900 revolutions per minute, and liquid concentrations of 1000 and 1380 grams per liter. Phases 2 and 3 involve modifications in the shape of vane and changes in the exit vane angle of the

impeller. Experimental tests indicate considerable improvement in pump efficiency. Analysis of the experimental data resulted in recommendations for changes in pump design.

- (f) 1, 2, 3 and 4 completed.
- (g) Considerable improvement in pump efficiency has been achieved.

(3085) STUDY OF SCALE EFFECT BETWEEN MODEL AND PROTOTYPE SPILLWAYS.

- (b) Laboratory project.
- (d) Graduate students' project.
- (e) A 1:100 scale two-dimensional model built of Chief Joseph Dam. Prototype crest pressures compared with the data obtained on the model.
- (f) Completed.
- (g) Very good correlation obtained between the model and prototype.

(3086) INVESTIGATION OF DESIGN CRITERIA OF SPUR DIKES.

- (b) Modjeski and Masters, Consulting Engineers, Harrisburg, Pa., Lehigh University Inst. of Research.
- (d) Analytical and experimental.
- (e) The project has been divided into four phases: (a) Literature survey; (b) analytical study; (c) experimental study in a fixed-bed model to determine the desired lengths and shapes of spur dikes to provide uniform velocity distribution in the waterway between bridge abutments; (d) experimental study in a movable-bed model to verify findings in part c. A spur dike has been defined as a projection extending upstream from the bridge abutments.
- (f) Phases (a), (b) and (c) completed; phase (d) active.
- (g) Preliminary investigation indicates that a properly designed spur dike can produce a fairly uniform velocity distribution between the abutments.

(3441) STUDY OF SCALE EFFECT BETWEEN MODEL AND PROTOTYPE 270 DEGREE BENDS FOR FLOW OF SILT-CLAY-WATER MIXTURES.

- (b) Laboratory project.
- (d) M. S. Thesis.
- (e) Four-, six-, and eight-inch diameter 90 degree elbows assembled to form 270 degree bends. Head loss measurements obtained for various flows and concentrations of silt-clay-water mixtures. Prediction equations have been investigated.
- (f) Completed.
- (g) No evidence of appreciable scale effect observed.
- (h) "Scale Effect on 270° Pipe Bends For Bingham Body Fluid," by P. L. Brach and J. B. Herbach, Fritz Engineering Laboratory Report No. 277-M-10, 1960.

(3442) SUGGESTED DESIGN CHANGES FOR A CENTRIFUGAL PUMP IMPELLER HANDLING DREDGED MUD.

- (b) Research report requirement of master's degree.
- (d) Theoretical.
- (e) Design changes in centrifugal pump impeller for handling mud are suggested on basis of past research and theoretical considerations.
- (f) Completed.

(3746) ANALYSIS OF FLOW PATTERN IN VOLUTE OF A CENTRIFUGAL PUMP.

- (b) Research report requirement of master's degree. District Engineer, U. S. Army Engineer District, Marine Division, Phila. Corps of Engineers.
- (d) Experimental.
- (e) High-speed movies of flow taken through a transparent plexiglas volute casing were analyzed. Velocity distribution as well as

- distribution of the exit angle between the impeller vanes as fluid leaves the impeller were determined.
- (f) Completed.
- (3747) FRICTION HEAD LOSSES IN CIRCULAR PIPES FOR A BINGHAM-BODY FLUID.
- (b) Laboratory project.
- (d) Experimental and theoretical.
- (e) The object of the study is the determination of the pipe flow characteristics of slurries of various concentrations. The slurries do not behave as fluids of constant viscosity so that it is not possible to use conventional methods for prediction of head losses in pipes conveying them. Tests are being conducted in 6-inch, 3-inch, and 2-inch pipelines with velocities from less than 1 fps to over 30 fps.
- (f) Suspended.
- (4154) DREDGE PUMP DESIGN.
- (b) National Bulk Carriers, Inc.
- (d) Experimental.
- (e) The objective of the investigation is to obtain the efficiency and head-capacity curves, to check the effect of the reduced vane exit angle, and to determine the efficiency of a model dredge pump while pumping silt-clay-water mixture of specific gravity equal to 1.17. The experimental tests were carried out on a 1/8 model pump of the National Bulk Carriers Hopper Dredge, S. S. Zulia.
- (f) Completed.
- (h) Report in preparation.
- (4155) WAVE RUN-UP ON COMPOSITE BEACHES.
- (d) Graduate students' project. Experimental, applied research for design.
- (e) The main object of the study is to verify existing equations for determining the height of wave run-up and obtain the limits of application of the equation for long beach berms.
- The study is conducted in a 67 ft. long, 2 ft. wide and 2 ft. deep wave channel equipped with pendulum-type wave generator and efficient absorbers.
- (h) "Effect of Berm on Wave Run-Up on Composite Beaches," by J. B. Herbich, R. M. Sorensen, J. H. Willenbrock, Transactions ASCE, Vol. 129, 1964.
- (4156) MULTIPLE DREDGE PUMP SYSTEMS.
- (b) National Bulk Carriers, Inc.
- (d) Experimental and theoretical.
- (e) The study is conducted to determine the effect on total production of dredge pumps with separate discharges and a combined discharge. The investigation is divided into two parts: (a) One pair of pumps is handling a mixture of water and solids, the other is pumping only water. It is required to determine what percentage of its normal output will the dredge pump passing the mixture attain. (b) If one of a pair of dredge pumps, both handling water-solids mixtures, is revolving slower than the other one, how does the total discharge compare to the total if the discharges were not combined?
- (f) Completed.
- (4344) STUDY OF THE GRAVITY WAVE REFLECTIONS FROM FLOATING RECTANGULAR BODIES.
- (b) Research report requirement of master's degree.
- (d) Experimental.
- (e) The object of the study is to determine the magnitude of wave reflections from rectangular floating bodies. Tests are being conducted in a 67-ft. long, 2 ft.-wide and 2 ft.-deep wave channel equipped with pendulum-type wave generator and efficient absorbers.
- (f) Completed.
- (4645) EFFECT OF LENGTH AND SPACING OF SPUR DIKES.
- (b) Laboratory report.
- (d) Experimental and theoretical; M.S. Thesis.
- (e) The object of the study is to determine the effect of length and spacing of spur dikes on the magnitude of scour in uniform flow. The experiments are conducted in a 10-ft. wide, 35-ft. long open channel with movable sand bed. Scour patterns are observed and analyzed.
- (5172) MEASUREMENT OF SLURRY FLOW BY USE OF 90° ELBOW METER.
- (b) National Bulk Carrier Inc., New York, New York.
- (d) Applied and Basic Research.
- (e) A four-inch 90° elbow meter was calibrated against a magnetic flow meter. A flow range of from 0-1100 gpm was effected in the calibration. Water and fine concentrations of silt-clay-water mixtures are included in the calibration tests. The basic theory of the "elbow meter" is discussed and an empirical mathematical relation between liquid concentration, differential head, and pipe velocity is presented and discussed. The feasibility of use of the elbow meter for flow measurement of slurry type flow is highly possible, but calibration of meter in place is recommended. Also, the viscous properties of the material metered are believed to play an important role in the meter's performance.
- (5173) SUCTION DREDGING LITERATURE SURVEY.
- (b) Ellicott Machine Corp., Baltimore, Maryland.
- (d) Applied and basic research.
- (e) This report is a brief review and summary of selected literature pertaining to equipment and methods associated with dredging practice and laboratory studies of dredge pumps. It consists of four parts: (1) Summary and discussion section. (2) Selected abstracts. (3) Annotated bibliography. (4) Bibliography.
- The discussion section consists of two parts. Part 1 discusses dredging equipment and dredging in general. Part 2 discusses dredge pumps.
- (5174) PERFORMANCE STUDY OF A 1:6 MODEL DREDGE PUMP.
- (b) Ellicott Machine Corporation, Baltimore, Md.
- (d) Applied and basic research.
- (e) Performance tests were made on five 1:6 scale model impellers. Each impeller was tested at four constant speeds over a wide range of heads and discharges. Water and two concentrations of a typical dredging mud were tested with each impeller at all four speeds. Various graphs and design application curves were developed for making similarity studies and designs in the homologous series of pumps.
- (5550) CAVITATION STUDIES ON A MODEL DREDGE PUMP.
- (b) Ellicott Machine Corp., Baltimore, Md.
- (d) Applied and basic research.
- (e) Effect of various pump design parameters on cavitation is being investigated. Water and two concentrations of a typical dredging mud are being used as dredging material in the laboratory. Other variables, in addition to geometric characteristics of the pump, include pump speed and rate of flow.
- (h) "Modification in a Dredge Pump Affect High Speed and Cavitation Characteristics," by W. P. Isaacs and J. B. Herbich, Fritz Laboratory Report No. 301.3, Lehigh Univ., 1964.

(5551) EFFECT OF LIQUID VISCOSITY ON CAVITATION OF A MODEL DREDGE PUMP.

- (b) Laboratory project.
- (d) Experimental and theoretical.
- (e) Research requirement of Master's degree.
- (f) Completed.
- (g) Cavitation tests were performed on three impellers in a model dredge pump. It was found that the impeller with the highest efficiency rating demonstrated the best cavitation performance. Tests of the impellers in silt-clay-water mixtures of various densities indicated that the viscosity of the liquid had a negligible effect on cavitation inception. The impeller rotational speed appeared to have no effect on the discharge at which cavitation began for constant head conditions.
- (h) "Cavitation Characteristics of a Model Dredge Pump," by V. R. Mariani, Fritz Laboratory Report No. 422, Lehigh University, 1963.

(5552) SCOUR OF FLAT SAND BEACHES DUE TO WAVE ACTION.

- (b) Laboratory project.
- (d) Experimental and theoretical.
- (e) Research requirement of Master's degree.
- (g) Stability of a horizontal sand bed deposited in shallow water in front of an impervious, smooth seawall under conditions in which the waves have not yet begun to break was investigated. Experimental studies have been performed in a two-dimensional wave channel in an effort to determine the rate, extent, and ultimate amount of scour of the flat sand bed for different conditions of water depth, wave height and length, and slope of sea wall.
- (h) "Scour of Flat Sand Beaches Due to Wave Action," by H. D. Murphy, Fritz Engineering Report No. 293.2, Lehigh Univ., 1964.

LOUISIANA STATE UNIVERSITY AND A AND M COLLEGE, Agricultural Engineering Department.

(5030) A GROUND-WATER PRESSURE TRANSDUCER.

- (b) Laboratory project.
- (c) Prof. Jackie W. D. Robbins, L.S.U. Agricultural Engineering Department, Baton Rouge, La.
- (d) Field investigation, development.
- (e) A study is being made to determine the applicability of an electrical gaging instrument for measuring ground-water pressure. Essentially, the instrument consists of a strain gage attached to a diaphragm. Hydrostatic pressure of ground-water acting against the diaphragm will cause the transducer to produce a measurable electrical signal and thus indirectly measure the magnitude of the ground-water pressure.
- (g) A pressure transducer has been devised which has characteristics suitable for field installation.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Civil Engineering, Hydrodynamics Laboratory.

Requests for reprints and Technical Reports should be addressed to Dr. Arthur T. Ippen, Professor of Civil Engineering, Hydrodynamics Laboratory, Mass. Inst. of Technology, Cambridge, Mass. 02139.

(307) MECHANICS OF STRATIFIED FLOW.

- (b) Laboratory project.
- (c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Theoretical and experimental; basic and applied research.
- (e) General studies on the characteristics of

stratified flows. Present studies are concerned with the problems of jet mixing in a stratified fluid and with selective withdrawal of a stratified fluid in porous media. Small density changes may be due to changes in fluid temperature, sediment in suspension, or changes in concentration of dissolved solids.

- (g) Experimental studies are under way on (1) the penetration of a vertical jet of liquid discharging upward into a more dense liquid having a vertical density gradient, and (2) the selective withdrawal from a two-layer system in porous media.

(1609) STUDY OF BEACH PROCESSES IN THE INSHORE AND FORESHORE ZONES.

- (b) Coastal Engineering Research Center, U.S. Army Corps of Engineers.
- (c) Professor P. S. Eagleson, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Experimental and theoretical; basic research. (S.M. thesis, Ph.D. thesis).
- (e) Study of the surface profile and internal kinematics of a shoaling oscillatory wave up to and beyond the breaker.
- (g) The theoretical phase is seeking an analytical description of the shoaling of finite amplitude waves which yields mass transport and is valid up to breaking. Preliminary results indicate that an exact irrotational solution may not exist. The experimental phase involves measurement of orbital velocities, static pressures and wave profile. Appropriate instrumentation is being developed.
- (h) "Experimental Study of Longshore Currents on a Plane Beach," by C. J. Galvin and P. S. Eagleson, Hydrodynamics Laboratory TR No. 63, May, 1964.
"Uniform Longshore Currents on a Plane Beach" by P. S. Eagleson, Proc. Latin American Congress on Hydraulics of the IAHR, Porto Alegre, Brazil, August, 1964.

(2801) INTERACTION OF WAVES WITH SUBMERGED AND FLOATING BODIES.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Prof. A. T. Ippen, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Theoretical and experimental; basic research.
- (e) The purpose of the study is to determine the wave reflecting and transmitting characteristics of different types of structures. Applications are made to floating or moored breakwaters and to wave transformation in variable geometry channels.
- (g) Two problems are currently under investigation: (1) Tubular Breakwater. Experiments on a tubular breakwater covered a series of tests on various lengths and number of tubes for a wide range of wave lengths and wave steepness. The effects of these variables on the transmission and reflection coefficients and on the wave power loss and on the forces on the breakwater are thus defined. (2) Effect of a Gradual Change of Depth and Width on Wave Transformation. A theory has been developed which is applicable to long waves encountering a gradual change in depth. These investigations are made in connection with a more general study on the transformation of long waves in the presence of submarine obstructions. A systematic investigation is now conducted to extend this work analytically and experimentally to the following phases: (a) Reflection and transmission characteristics for gradual changes in depth. (b) Reflection and transmission characteristics for gradual changes in width. (c) Combinations of a and b.
- (h) "Wave Reflection and Transmission in Channels of Gradually Varying Depth," by A. T. Ippen, A. M. Z. Alam, and E. L. Boudoumis, Hydrodynamics Laboratory TR No. 72, July, 1964.
"Breakwater Characteristics of Open-Tube

- Systems," by A. T. Ippen and E. L. Bourodimos, (3746) DISPERSION IN POROUS MEDIAN AND WASTE WATER
Hydrodynamics Laboratory TR No. 73, July, 1964. RECHARGE.
- (2802) EXPERIMENTAL STUDY OF WAKE MECHANICS.
- (b) Laboratory project.
 - (c) Professor P. S. Eagleson, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Experimental and theoretical; basic research (S.M. thesis).
 - (e) A study of the effect of trailing edge geometry and flow-induced body vibration on spanwise correlations of instantaneous wake structure for flat plates.
 - (g) Spanwise spatial correlations of total head fluctuations as obtained from cross power spectrum indicate the feedback from vibratory motion to forcing moment to result primarily from increasing spanwise wake coherence.
 - (h) "Spanwise Correlation of Instantaneous Wake Structure for Flat Plates: The Effect of Transverse Body Vibration," by J. J. Turner and R. L. Wartens, S.M. and Naval Eng. Thesis, M.I.T., Course XII-A, June, 1964.
- (3443) COMPUTER SIMULATION OF THE COMPLETE TRANSIENT PROBLEM IN A HYDRO-POWER PLANT.
- (b) U. S. Army Corps of Engineers, Missouri River Division.
 - (c) Prof. A. T. Ippen, Professor P. S. Eagleson.
 - (d) Theoretical, field tests; applied research.
 - (e) Development of a digital computer program of general utility and proven validity for performing design analyses involving the response of hydro-power plant systems to load fluctuation.
 - (g) Digital computer programs have been written which for a wide range of hydraulic geometries will yield the time variation of the important hydraulic and mechanical variables for an arbitrary time variation in electrical load under the assumption of an isolated system. The results of these programs compare well with field test measurements. Final reports and a user's manual are being prepared.
 - (h) "Hydro-Power Plant Transients Part II: Response to Load Rejection," by F. E. Perkins, A. Tedrow, P. S. Eagleson, and A. T. Ippen, Hydrodynamics Laboratory TR No. 71, July, 1964.
 - "Hydro-Power Plant Transients Part III: Response to Variable Load," by F. E. Perkins, A. Tedrow, P. S. Eagleson, and A. T. Ippen, Hydrodynamics Laboratory TR No. 79, Jan., 1965.
- (3444) EFFECTS OF BASIN GEOMETRY AND VISCOUS DAMPING ON THE AMPLITUDE OF RESONANT OSCILLATIONS IN HARBORS.
- (b) Office of Naval Research, Dept. of the Navy.
 - (c) Prof. A. T. Ippen, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Theoretical and experimental; basic research.
 - (e) Investigation of the response of a harbor to waves incident on the harbor opening, with open ocean conditions simulated in a basin of finite size.
 - (g) The response of a rectangular harbor connected to the open sea was studied both analytically and experimentally. Solutions were obtained for the harbor response to wave incident from the ocean. Experiments were conducted on fully-open as well as partially-open harbors of different geometrical properties. Wave filters and absorbers were used to simulate the conditions of an open sea in a finite basin. It was found that the theoretical solutions accurately predict the resonant periods of the harbor. Good understanding was also reached regarding the "harbor paradox." Investigations revealed its relation to viscous damping and to the response of a harbor to waves of a continuous power spectrum.
 - (h) "Wave Induced Oscillations in Harbors: The Effect of the Variation of Geometric Parameters on the Response of Rectangular Harbors," by A. T. Ippen and Q. N. Fattah, Hydrodynamics Laboratory TR No. 70, June, 1964.
- (b) U. S. Public Health Service, Division of Water Supply and Pollution Control.
 - (c) Professor D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Theoretical and experimental; basic research (doctoral thesis).
 - (e) A numerical analysis to determine the amount of dispersion between miscible fluids of differing quality in radial, confined flow through a porous medium has been completed. An investigation of dispersion arising from the injection of a contaminant through a recharge well and the withdrawal of fresh water through a pumping well, both pumping at the same rate, in an infinite, confined aquifer is being carried out currently. Results will be important to engineering projects in the recharging of aquifers with reclaimed waste water.
 - (g) A general correlation has been made of known measurements of the longitudinal and lateral dispersion coefficients, using the correct dimensionless representation. Measurements have been made of the amount of dispersion (mixing) that occurs when a single well, pumping at a steady rate, discharges reclaimed waste water into an infinite, homogeneous, isotropic aquifer. A numerical solution of the governing differential equation has been obtained. This solution is compared with several approximate methods of solution to the differential equation and to some known field and experimental results. In the final phase, the problem of two-dimensional dispersion, arising from the steady injection of a contaminant through a recharge well and the steady withdrawal of fresh water by a pumping well (both pumping at the same rate), is being investigated experimentally and numerically. A sand model of this two-well flow problem has been constructed.
 - (h) "Intruded Salt-Water Wedge in Porous Media," by R. R. Rumer, Jr. and D. R. F. Harleman, Proc. ASCE, Vol. 89, No. HY6, Nov., 1963.
 - "Longitudinal Dispersion in Non-Uniform Porous Media," by K. Mohtadullah, S. M. Thesis, June, 1964.
- (3749) RESISTANCE OF ENCLOSED ROTATING DISKS.
- (b) Office of Ordnance Research, U. S. Dept. of the Army.
 - (c) Professor J. W. Daily, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Experimental and analytical; basic research.
 - (e) Effect of superposed throughflows on boundary layers, secondary motions and surface resistance of enclosed rotating disks.
 - (f) Completed.
 - (g) Quantitative measurements of torque, fluid velocity and pressure distributions and unsteady periodicities were made using smooth disks in an enclosure with variable axial clearance. The case of separate boundary layers with a rotating core between disk and stationary walls was modelled mathematically and checked against experiment using digital computations.
 - (h) "Enclosed Rotating Disks with Superposed Throughflow: Mean Steady and Periodic," by J. W. Daily, W. D. Ernst, V. V. Asbedian, Hydrodynamics Laboratory TR No. 64, April, 1964.
- (3750) WAVE FORCES ON STRUCTURES.
- (b) Laboratory project.
 - (c) Prof. D. R. F. Harleman, Massachusetts Institute of Tech., Cambridge, Massachusetts 02139.
 - (d) Theoretical and experimental; applied research (S. M. Thesis).
 - (e) The objective is the development of design

- information for wave forces on immersed objects.
- (g) Analytical procedures have been developed to determine the variation with time of the lateral forces developed on a vertical cylinder due to eddy shedding. Experiments are being run to determine the magnitude of the lateral forces as a function of cylinder diameter and wave characteristics. The phasing of the vortex shedding forces is being correlated with the wave motion.
- (h) "Transverse Forces on Cylinders Due to Vortex Shedding in Waves," by K. Chang, S.M. thesis, January, 1964.
- (4159) INSTRUMENTATION SYSTEM FOR THE ANALYSIS OF COMPLEX WAVE FORMS.
- (b) National Science Foundation.
- (c) Prof. A. T. Ippen, Prof. P. S. Eagleson.
- (d) Basic research facility.
- (e) Selection and assembly of an analog computer for the calculation and plotting of correlation and spectrum functions. Design and construction of a mechanical time delay mechanism.
- (g) Data are acquired on a portable, multichannel FM tape transport. A second transport permits frequency multiplication through re-recording and provides a 120-foot tape loop capability for the repetitive analysis of short records. Matched filters allow the determination of cross power spectral densities as well as the power spectral density of a single signal. The tape loop transport is being fitted with a mechanical time delay mechanism for the determination of correlation functions. Output of all operational modes is through an x-y plotter.
- (4160) MOTION OF SUBMERGED BODIES BELOW A FREE SURFACE.
- (b) Office of Naval Research, Dept. of the Navy.
- (c) Prof. J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Experimental and theoretical; basic research (S.M. thesis).
- (e) An investigation of the turbulent wakes generated by two- and three-dimensional bodies moving beneath the free surface. The effects of density stratification are included in the study.
- (g) Velocity distributions have been measured at various distances behind a two-dimensional body moving at different depths of submergence in a homogeneous fluid, and at the interface of a two-layered density-stratified fluid. The turbulent mixing between the two layers has been measured by measuring concentration profiles of the tracer, initially present in only the lower, heavier layer, at various distances behind the body. The vertical-diffusion coefficient has been found to decrease significantly with increasing density difference between the two fluid layers. The density stratification also causes the wake width to decrease with increasing distance behind the body after attaining a maximum value at a moderate distance behind the body. The velocity profiles in the stratified fluid are of the exponential, similar type, but cannot be predicted using the methods developed for homogeneous fluids, because of the collapse of the wake width.
- (h) "Two-dimensional Turbulent Momentum Wakes in Density Stratified Fluids," by F. A. Froebel, S.M. thesis, June 1964.
- "Two-dimensional Turbulent Wakes in Density-Stratified Liquids," by J. F. Kennedy and R. A. Froebel, Paper No. 64-WA/UNT-11, ASME Winter Annual Meeting, December, 1964.
- (4648) MECHANICS OF AERATION AND DISPERSION IN RIVER AND ESTUARY POLLUTION.
- (b) Public Health Service, Division of Water Supply and Pollution Control.
- (c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Experimental and theoretical; basic research (doctoral thesis).
- (e) (1) A basic study of estuary dispersion in an oscillating flow with throughflow superimposed. Extension of Taylor analysis of longitudinal mixing in estuary type flows. Study of similitude of distorted estuary models in regard to distribution of pollutants in fresh water region of the estuary.
- (2) A study of the basic mechanism of oxygen transfer from the atmosphere into turbulent water.
- (g) (1) Experimental and analytical investigations are underway on mixing in a pipe line with oscillating plus throughflow. Results indicate that incorrect longitudinal concentration distributions may be obtained from tests in estuary models if one-to-one ratio is assumed for concentrations in model and prototype.
- (2) Turbulence is produced with oscillating screens in a shallow tank of initially deaerated water, and the dissolved oxygen is measured as a function of time and depth by means of an electro-chemical probe. One of the objectives is to separate the effects of turbulence on oxygen transfer across the surface from the effects of turbulent diffusion within the body of the fluid.
- (h) "Dispersion of Pollutants in Estuary-Type Flows," by E. R. Holley, Jr., Sc.D. Thesis, September, 1964.
- "The Significance of Longitudinal Dispersion in the Analysis of Pollution in Estuaries," by D. R. F. Harleman, Proc. 2nd Int. Conf. on Water Pollution Research, Tokyo, Sec. I, paper No. 13, Pergamon Press, Inc., August, 1964.
- (4649) TURBULENT TRANSFER MECHANICS OF FLUID SUSPENSIONS OF SOLID PARTICLES.
- (b) Pioneering Research Program, Institute of Paper Chemistry.
- (c) Professor J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Experimental; basic research (Master's and Doctor's thesis).
- (e) Basic investigation of turbulent transfer mechanics of liquid flows with suspended particles.
- (g) Velocity profiles and friction factors were measured for concentrated suspensions of plastic particles in water flowing in a circular two-inch tube in a special flow facility. Measurements were made for both spherical and non-spherical particles. Special experiments are being conducted to determine the mean velocities of the water and of the particles. Total-head probes are being calibrated in a special contraction nozzle to obtain precise data on the effect of the suspended particles on the velocity measurements. Instrumentation is being assembled to measure the turbulence in the flowing suspensions.
- (h) "Rigid Particle Suspensions in Turbulent Shear Flow: Measurement of Total Head, Velocity, and Turbulence with Impact Tubes," by J. W. Daily and R. L. Hardison, Hydrodynamics Laboratory TR No. 67, April, 1964.
- "Rigid Particle Suspensions in Turbulent Shear Flow: An Improved Flow Facility and Measurements with 0.0255" Spheres," by J. W. Daily and C. C. Shen, Hydrodynamics Laboratory TR No. 68, May, 1964.
- "Rigid Particle Suspensions in Turbulent Shear Flow: Size Effects with Spherical Particles," by J. W. Daily and C. P. R. Roberts, Hydrodynamics Laboratory TR No. 69, June 1964.
- "Fine Rigid Particles in Flowing Suspensions," by C.P.R. Roberts, S.M. Thesis, June, 1964.
- (4650) HURRICANE BARRIER STUDIES.

- (b) U. S. Army Engineer Division, New England, Corps of Engineers.
- (c) Professor R. T. McLaughlin, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Analytical; applied research.
- (e) Determination by digital computation of waves produced by storms in the vicinity of Narragansett Bay, Rhode Island, and selection of design wave for hurricane barriers at the entrance to the bay. Determination of optimum geometry for the barriers.
- (f) Completed.
- (h) "Study of Hurricane Barrier for Lower Narragansett Bay," by R. T. McLaughlin and M. A. Anton, Hydrodynamics Laboratory TR No. 66, February, 1964.
- (4654) A NEW METHOD FOR THE SYSTEMATIC INVESTIGATION OF SEDIMENT TRANSPORT.
- (b) National Science Foundation.
- (c) Prof. A. T. Ipsen, Prof. P. A. Drinker, Prof. L. W. Gelhar, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Theoretical and experimental; basic research.
- (e) A research program to develop the general characteristics of the flow of fluid-sediment mixtures and of the interaction of fluid flow with movable boundaries.
- (g) A study of sediment transport by shear flow in the annulus between two rotating drums rather than by flow in a channel has been initiated. A new experimental apparatus which replaces the commonly employed longitudinal channel by an annular channel between two rotating drums has been designed and built. The normal gravitational field is replaced by a centrifugal force field. With the cylindrical drums rotating at different relative speeds a large variety of flow conditions can be established in the "endless" annular channel, covering a wide range of tractive forces on the sediment deposited on the wall of the outer drum under various modes of relative motion. The difficult recirculation of sediment and liquid necessary in conventional flumes is thus avoided.
- (5114) ROUTING UNSTEADY FLOWS FROM HYDROELECTRIC PLANTS FOR OPTIMIZATION OF NAVIGATION AND PEAK POWER PRODUCTION.
- (b) Tennessee Valley Authority.
- (c) Prof. R. T. McLaughlin, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Analytical; applied research.
- (e) Theoretical analysis of rapid changes of discharge in open-channels and the use of mathematical models of such flows in digital and analog computers.
- (g) A method of characteristics especially suitable for large and rapid changes of discharge is being applied to a channel having quite general geometry.
- (h) "A Digital Computer Simulation of Unsteady Flow in Rectangular Non-Prismatic Channels," by J. E. Dailey, S.M. Thesis, June, 1964.
- (5115) SYSTEMS METHODOLOGY FOR WATER-RESOURCE PLANNING IN A REGIONAL DEVELOPMENT CONTEXT.
- (b) M.I.T. Inter-American Program in Civil Engineering.
- (c) Prof. R. T. McLaughlin, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Theoretical and analytical; basic research.
- (e) Research on the use of mathematical models and systems analysis in planning for comprehensive development of water resources in river basins or other hydrologic units. The relationship of such developments to the social and economic activity of the region in which the unit is located is also being considered.
- (g) An existing mathematical model for simulating a single multi-purpose reservoir is being modified for more sophisticated handling of operating decisions during the simulation. Simplified mathematical models are being investigated for possible use in obtaining approximate answers in the early stages of a planning study. The results of the simplified models are being checked against results of simulation.
- (h) "A Dynamic Programming Model for Reservoir Simulation," by R. M. Males, S.M. thesis, September, 1964.
- (5116) DEFINITION OF WATER-RESOURCE PROBLEMS IN LATIN AMERICA.
- (b) M.I.T. Inter-American Program in Civil Engineering.
- (c) Prof. R. T. McLaughlin, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Area survey; for problem identification.
- (e) General study of water-resource problems of Latin America to define specific and significant problems that seem to be areas of fruitful research.
- (f) Completed.
- (g) Preparation of final report in process.
- (h) "Problems of Community Water Supply in Relation to Water Resource Development in Latin America," by J. W. Bulkley, S.M. thesis, September, 1963.
- (5117) ANALYSIS AND SYNTHESIS OF HYDROLOGIC SYSTEMS.
- (b) M.I.T. Inter-American Program in Civil Engrg.
- (c) Prof. P. S. Eagleson, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Experimental and theoretical; basic research (doctoral and S.M. Thesis).
- (e) Development of improved analytical techniques for the prediction of the time variation in stream flow at some point in a drainage basin due to a given temporal and areal distribution of precipitation. Development of the means for synthesizing these predictors in the absence of long term hydrologic records.
- (g) The similarity relationships governing surface runoff have been derived and from these the useful range of operation of model catchments has been determined. Instrumentation for a model catchment has been designed and is being built.
- (5118) MECHANICS OF SEDIMENT RIPPLES AND DUNES.
- (b) Laboratory project.
- (c) Prof. J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Theoretical; basic research (Master's and Doctor's thesis).
- (e) The formation of sediment ripples and dunes by uniform free-surface flow, uniform infinite flow, and oscillating flow are being investigated as a stability problem by using potential flow solutions for fluid motion over a small-amplitude wavy bed and a sediment transport law in which the transport rate at any point is proportional to a power of the velocity near the bed at some distance upstream. The kinematics of the resulting sediment motion are used to determine the conditions for which the bed waves will grow, and the behaviour of the resulting bed features.
- (g) Formulas for the wave length, velocity of movement, and amplitude of ripples and dunes have been developed, and the conditions for formation bed waves have been delineated. The investigation is now being directed toward development of a method for predicting the friction factor of uniform flows over sand beds in alluvial channels.
- (h) "The Formation of Sediment Ripples in Closed Rectangular Conduits, and in the Desert," by J. F. Kennedy, Journal of Geophysical Research, 69, April 8, 1964. "The Formation of Wave-Generated Sedimented Ripples," by J. F. Kennedy and M. Falcon-Ascanio, Proc. 1st Latin-American Congress,

Porto Alegre, Brazil, August, 1964.

(5119) TIDAL, SALINITY AND SEDIMENTATION PROBLEMS IN LAKE MARACAIBO CHANNEL, VENEZUELA.

- (b) M.I.T. Inter-American Program in Civil Engrg.
- (c) Prof. A. T. Ippen, Prof. E. Partheniades, and Prof. J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Theoretical and experimental; basic research.
- (e) The primary purpose of this project is to investigate the laws governing tide propagation and salt water intrusion in estuarial channels, and erosion, transport, and deposition of fine material in estuaries. The long range goals of these studies are: (a) To make possible a theoretical or an experimental prediction of salinity and current velocity changes caused by certain engineering operations in estuarial areas; (b) to provide enough information for a reasonable theoretical or experimental evaluation of fine sediment transport and deposition particularly in estuarial navigation channels; (c) to establish rational criteria for the stability of channels with cohesive bed and banks and their protection against objectionable erosion.
- (g) An annular rotating "endless" channel has been constructed. An annular plate within the annular channel rotates in opposite direction to the channel, inducing shear stresses within the fluid. The shear stress on the annular plate is measured by means of calibrated strain gages. This setup will be used for an investigation to determine what factors are important in the erosion and deposition of cohesive soils. Extensive field research was conducted during the summer of 1964 within the Maracaibo estuary to determine the sediment motion, salinity variations, and the major source or sources of sediment. An interesting sediment and salinity distribution pattern was disclosed, which eliminated certain sources of sediment and contributed significantly to the understanding of the general picture. Preparations for determination of internal currents within the Maracaibo estuary using Rhodamine B as a water tracer are under way. Some flume experiments were carried on at the University of Zulul, Maracaibo on deposition rates of estuarial sediment.

- (h) "A Summary of the Present Knowledge of the Behavior of Fine Sediments in Estuaries," by E. Partheniades, Hydrodynamics Laboratory TN No. 8, June, 1964.

(5120) THE FEASIBILITY OF ROTATING MODELS IN THE STUDY OF CIRCULATION PATTERNS IN LARGE LAKES.

- (b) Laboratory project.
- (c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Theoretical and experimental; basic research.
- (e) A study of the feasibility of small scale models in which similitude with respect to gravity and Coriolis forces is obtained. Velocity and time scales are obtained from Froude conditions for a distorted model. Model is rotated to obtain effect of Coriolis acceleration.
- (g) Surface current patterns on a small model of Lake Michigan have been obtained for a constant wind field both with and without rotation of the model. The effect of a vertical density stratification on current patterns has been studied. The production of a thermocline by infrared heating of the model surface has also been investigated. Results indicate that rotation of the model produces marked differences in circulation patterns when compared to non-rotating model having the same wind pattern over the surface. A small model of Lake Maracaibo (Venezuela) has been constructed for the purpose of studying the peculiar pattern of salinity distribution which exists in the lake. Results indicate that pattern is produced by

interaction of wind generated currents and Coriolis effect.

- (h) "A Study of Circulation and Thermocline Development in a Small Scale Rotating Lake Model," by R. M. Bunker and J. B. Hall, S.M. thesis, January, 1964.
- "Circulation and Thermocline Development in a Rotating Lake Model," by D. R. F. Harleman, R. M. Bunker, and J. M. Hall, Proc. 7th Conf. on Great Lakes Research, Pub. No. 11, Great Lakes Research Div., University of Michigan, 1964.
- "A Study of the Salinity Stratification of a Distorted Rotating Lake Model," by P. J. Stockhausen, S.B. thesis, June, 1964.

(5539) FREE SURFACE FLOW OVER THE WAVY BED.

- (b) Laboratory project.
- (c) Prof. J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Experimental and theoretical; basic research (Master's thesis).
- (e) An investigation of a free surface flow of a real fluid over a small-amplitude sinusoidal bed in a rectangular-cross-section channel. Velocity profiles upward from the bed and outward from the vertical side walls have been measured at various locations along a sinusoidal-shaped wavy bed, and along an isolated sinusoidal hump in the channel bottom. It has been found that the displacement thickness of the straight vertical walls varies periodically along the length of the channel with the same period as the wavy bottom. This undulation in the displacement thickness generates diagonal free-surface waves which criss-cross the flume, a new wave being generated by each wave on the channel bottom. Pressure and velocity measurements indicate that the perturbation in the displacement thickness is caused by secondary currents resulting from the interaction of the boundary layers of the vertical side walls and the distortion of the vertical and lateral pressure gradients caused by the curvature of the bed. The orientation of the diagonal wave is in good agreement with that predicted using small-amplitude wave theory.

(5540) MINIMUM-COST DESIGN OF PIPE NETWORKS.

- (b) Un-sponsored laboratory project.
- (c) Professor R. T. McLaughlin, Mass. Inst. of Technology, Cambridge, Mass. 02139.
- (d) Analytical, design (Master's thesis).
- (e) Marginal analysis by means of a digital computer is used to find the pipe network that delivers prescribed amounts of water at fixed points with a minimum cost of network and pumping.

(5541) HYDROLOGIC SYSTEMS INVESTIGATIONS.

- (b) M.I.T.-Sloan Basic Research Grant.
- (c) Prof. P. S. Eagleson, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Theoretical; basic research.
- (e) Study of the applicability of communication theory to the analysis of hydrologic systems.
- (g) Theoretical criteria have been developed for the design of precipitation and streamflow instruments.

(5542) CAVITATION NEAR SURFACES OF DISTRIBUTED ROUGHNESS.

- (b) U.S. Army Research Office - Durham.
- (c) Prof. Z. Kronfeld, Prof. P. S. Eagleson, Mass. Inst. of Tech., Cambridge, Mass. 02139.
- (d) Experimental and theoretical (Master's thesis).
- (e) The influence of various types of artificially roughened surface on the inception of cavitation and the reciprocal effect of collapsing cavities upon those surfaces.

(5543) DISPERSION OF POLLUTANTS IN HETEROGENEOUS

AND ANISOTROPIC AQUIFERS.

- (b) Public Health Service, Div. of Water Supply and Pollution Control.
 - (c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Analytical and experimental (Doctoral thesis).
 - (e) Study of the dispersion and mixing in miscible fluid displacement in heterogeneous and anisotropic porous media. Initial phase of the study is concerned with longitudinal dispersion in a non-homogeneous aquifer consisting of alternating layers of uniform sand of two different sizes.
- (5544) TECHNIQUES OF MODELLING THE SOLAR POND IN THE LABORATORY.
- (b) Laboratory project.
 - (c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Experimental and analytical (Doctoral thesis).
 - (e) The solar pond is used to store solar energy by absorption of radiation in a dense layer at the bottom of a pond. The object of the research is to (1) find an analytic prediction for the temperature distribution in a pond with and without a black body absorber at the bottom for a specified radiation at the surface, (2) investigate the effect of wind and terrestrial rotation, (3) find suitable ways of withdrawing hot water and replenishing the pond with cool water.
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- MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Mechanical Engineering.
- (4490) COOLING OF HIGH-PERFORMANCE ELECTROMAGNETS.
- (b) M.I.T. National Magnet Laboratory.
 - (c) Prof. Arthur Bergles, M.I.T., Cambridge, Mass. 02139.
 - (d) Experimental and theoretical; basic and applied research; bachelor's, master's, and doctor's theses.
 - (e) This project has been concerned with the prediction of heat transfer and pressure drop under conditions simulating those encountered in high-performance electromagnets. Nonboiling and boiling heat transfer with water are being studied. Techniques of augmenting heat transfer are being considered.
 - (g) Data have been taken and correlations proposed for the prediction of heat transfer, pressure drop, and burnout for forced-convection surface boiling. The conditions for stability in parallel-channel systems have been defined. Augmentative techniques were surveyed and investigations of fluid vibrations and additives have been performed.
 - (h) "Pressure Drop with Surface Boiling in Tubes of Small Diameter," T. Dormer, Jr. and A. E. Bergles, M.I.T. Engineering Projects Laboratory Technical Report No. 8767-31, Sept. 1964.
"The Influence of Flow Vibrations on Forced-Convection Heat Transfer," A. E. Bergles, Journal of Heat Transfer, Trans. ASME, Vol. 86, pp. 559-560, 1964.
"Survey and Evaluation of Techniques to Augment Convective Heat Transfer," A. E. Bergles and H. L. Morton, M.I.T. Engineering Projects Laboratory Technical Report No. 5382-34, January 1965.
- (4498) USE OF ELECTROCHEMILUMINESCENCE IN BOUNDARY LAYER STUDIES.
- (b) Laboratory project.
 - (c) Mr. George S. Springer, Room 3-264, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Applied research.
 - (e) The technique of electrochemiluminescence is used to measure mass transfer rates and to visualize separation and transition in boundary layers.
- (g) Experimental results were obtained showing that the light generated on a given surface is proportional to the mass transfer of the chemiluminescence substance to the surface.
 - (h) "Electrochemiluminescence, A Method of Flow Visualization with Applications to Heat Transfer," B. S. Thesis, M. Potash, M.I.T., 1963.
"An Apparatus for Applying the Technique of Electrochemiluminescence to Boundary Layer Studies," Th. Schiller, M. S. Thesis, M.I.T., 1964.
"Use of Electrochemiluminescence in the Measurement of Mass Transfer Rates," The Rev. Sci. Instruments, 35, 1277-1280 (1964).
- (4979) MULTIPLE CHANNEL NATURAL CIRCULATION SYSTEMS.
- (b) National Science Foundation.
 - (c) Prof. S. William Gouse, Jr., Assistant Professor of Mechanical Engineering, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Basic research; experimental and theoretical.
 - (e) An investigation of the occurrence of various flow configurations in multiple channel, natural circulation systems with various fluids under conditions of nonuniform heat input ratio. The parameters governing such phenomena as reverse flows, multi-directional flows in a single channel, developing entrance flows, and transition to turbulence are examined.
 - (h) "Flow and Stability Problems in Multiple-Channel Natural Convection Systems," J. C. Chato, Trans. Am. Nuclear Soc., 5 No. 1, 147, (1962).
"Natural Convection Flows in Parallel-Channel Systems," J. C. Chato, ASME Paper No. 62-WA-169, to be published in the Trans. ASME J. of Heat Transfer.
- (4980) FLOW OF CONDUCTING FLUIDS IN A MAGNETIC FIELD.
- (b) Mass. Inst. of Technology.
 - (c) Mr. William H. Heiser, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Analysis and experiment.
 - (e) The flow pattern from a vertical, cylindrical tank which is emptying through a hole in the bottom can be severely altered by a vertical magnetic field if the fluid is a conductor. This project demonstrates this effect experimentally and provides the means for determining the size of this effect.
 - (f) Analysis and experiment completed for a simple form of this type of flow. The more difficult forms are being treated.
 - (g) Encouraging agreement between analysis and experiment indicates that the general problem can be solved.
- (4982) FUNDAMENTAL INVESTIGATION OF HEAT TRANSFER AND FLUID FLOW INSIDE A HORIZONTAL TUBE EVAPORATOR.
- (b) American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.
 - (c) Prof. S. William Gouse, Jr. Asst. Prof. of Mechanical Engineering, Mass. Inst. of Tech., Cambridge, Mass. 02139.
 - (d) Basic research; experimental and theoretical.
 - (e) To conduct a visual and quantitative study of the fluid mechanics of a horizontal tube evaporator in order to clarify the confusion which presently exists in the interpretation of experimental results as concerns heat transfer mechanisms.
 - (h) "Heat Transfer and Fluid Flow Inside a Horizontal Tube Evaporator Phase I", S. William Gouse, Jr., Karl G. Couman, M.I.T. Eng. Proj. Lab. Report DSR 9649-1, June, 1964, Mechanical Eng. Dept.
- (4983) DETERMINATION OF THE STATE OF THE ART IN TWO-PHASE GAS-LIQUID FLOW PHENOMENA.

- (b) Office of Naval Research (Nonr-1841(73)).
(c) Prof. S. William Gouse, Jr., Asst. Prof. of Mechanical Engineering, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Literature search and review.
(e) Conduct a world wide search of the literature on various aspects of two-phase gas-liquid flow, index the literature and review the state of the art in various problem areas.
(h) "Void Fraction Measurement," S. W. Gouse, Jr., M.I.T., Mechanical Engineering Dept., Eng. Projects Lab. Report DSR 8734-2, AD 600 574, April 1964.
"An Introduction to Two-Phase Gas-Liquid Flow," M.I.T., Mechanical Engineering Dept., Eng. Projects Lab., Report DSR 8734-3, June 1964.
"An Index to the Two-Phase Gas-Liquid Flow Literature, Part II," S. W. Gouse, Jr., M.I.T., Mechanical Engineering Dept., DSR 8734-4, September 1964.
"Two-Phase Gas-Liquid Flow Oscillations: Preliminary Survey," M.I.T., Mechanical Engineering Department, Eng. Projects Lab. Report DSR 8734-5, July 1964.
- (5553) HYDRAULIC JUMP IN SWIRLING FLOW.
(b) Laboratory project.
(c) Mr. Joseph L. Smith, Jr., Mech. Eng. Dept., Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Master's thesis.
(e) To observe and predict the change of the free surface radius caused by a hydraulic jump in a swirling flow.
- (5554) TWO-PHASE DIFFUSER FLOW STUDIES.
(b) M.I.T. Solar Energy Fund.
(c) Prof. S. William Gouse, Jr., Asst. Prof. of Mechanical Engineering, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Basic research; experimental and theoretical.
(e) To conduct an experimental and analytical study of the deceleration of two-phase gas-liquid flows in a diverging channel.
- (5555) PULSATING FLOW IN FLEXIBLE TUBES.
(b) Massachusetts Heart Association, National Institutes of Health.
(c) Prof. A. H. Shapiro, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical; basic and applied research; master's and doctoral theses.
(e) The project aims at an understanding of the larger vessels of the vascular system. The current studies involve the dynamics of the pulsing flow of liquid through a flexible tube.
(g) Experimental equipment in operation. Non-linear theory under development.
- (5556) FISH PROPULSION.
(b) Shell Oil Co.
(c) Prof. E. F. Kurtz, Jr., Mass. Inst. of Tech., MIT Room 3-356, Cambridge, Mass. 02139.
(d) Theoretical, basic research, Master's Thesis.
(e) Fish are modelled as infinitely long flexible cylinders. The flexing motion consists of waves propagating the axis. The velocity field, thrust, and propulsive efficiency have been determined.
(h) In preparation.
- (5557) MOMENTUM FLUXES IN TWO PHASE FLOW.
(b) U. S. Atomic Energy Commission.
(c) Mr. Peter Griffith, Room 7-046, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) To measure momentum fluxes in two phase gas liquid flow.
(e) A two phase glow is turned through 90° and the force on the turning T is measured.
(f) Experimental equipment operating.
- UNIVERSITY OF MASSACHUSETTS, School of Engineering.
(2561) HYDROLOGY STUDIES IN WESTERN MASSACHUSETTS.
(b) Cooperative with the U. S. Soil Conservation Service, U. S. Geological Survey, and Mass. Water Resources Commission.
(c) Prof. George R. Higgins, Engineering Research Institute, Univ. of Mass., Amherst, Mass. 01003.
(d) Experimental-field and laboratory; for design of watershed yield, flood peak reduction and general information.
(e) Mass curve and Duration curve studies for reservoir and water-shed yield have been done for nearly all the gaged streams in Massachusetts. The purpose of the study is to determine general information for optimum use of water resources of the state. Particular emphasis on recreational aspects and low flow characteristics is presently being considered.
(h) Progress reports were submitted to the University Research Council in 1959 and 1960. Reports for the Massachusetts Water Resources Commission were submitted in 1963 and 1964.
- (4166) AGITATION CHARACTERISTICS IN LIQUID-LIQUID SYSTEMS.
(b) National Science Foundation; University of Massachusetts Research Council.
(c) Associate Dean E. E. Lindsey, Engineering Research Institute, University of Mass., Amherst, Massachusetts 01003.
(d) Experimental; basic research for master's thesis.
(e) Two immiscible or partly miscible liquids are used. Dispersions are produced in a dynamometer agitator and particle sizes of the sampled dispersion are measured by a light scattering technique. One thesis was concerned with developing the technique and study in geometrically similar, baffled tanks, another thesis with transient change in drop sizes at the start of agitation. Current project is to study variations in geometry. Work is continuing on development of light-scattering probe to measure particle size directly in the mixing tank.
(g) Primary peaks in the drop size distribution occurred at 1 to 3 microns, secondary peaks at about 30 microns. Drop size distribution is essentially identical in geometrically similar vessels of different size of equal power/volume. There is a slight decrease in size with increased agitator speed. Comparison of two liquid systems indicates drop size decreases with increasing viscosity. Steady state drop size distribution occurred in 30 to 60 minutes.
- (4167) PRESSURE DROP ACROSS FITTINGS.
(b) Laboratory project.
(c) Dr. Kenneth D. Cashin, Prof. of Chemical Engineering, Dept. of Chemical Engineering, Univ. of Mass., Amherst, Mass. 01003.
(d) Experimental; Senior Work Scholarship project; basic research.
(e) Pressure drop is measured for a number of different pipe fittings placed in series and at different spacings; to determine effect on pressure drop of closely spaced fittings as compared with those widely separated.
(g) Two (or more) similar fittings when very closely spaced (1 to 4") give less pressure drop than the same two (or more) fittings when widely spaced (10" or more). The difference between the two different pressure drops decreases with increasing Reynold's number.
- (4656) THE EFFECT OF NON-NEWTONIAN FLUID INJECTION ON THE TURBULENT BOUNDARY LAYER OF A FLAT PLATE.
(b) Laboratory project.

- (c) Dr. Charles E. Carver, Jr., Prof. of Civil Engrg., Univ. of Mass., Amherst, Mass. 01003
 - (d) Experimental; basic research.
 - (e) A number of non-Newtonian additives, including two types of guar gum, CMC, and a polyoxide mixed with water, are injected in the laminar boundary layer near the leading edge of a flat lucite plate at zero incidence through a transverse slot in the plate. The flat plate is installed in a small water tunnel through which clear water flows with a free stream velocity U_0 . A lead zirconate pressure transducer is installed flush with the plate a few inches downstream of the injection slot such that the overlying boundary layer is turbulent. It is found that no detectable decrease in turbulent intensity occurs with injection as opposed to no injection, for all additives employed. Concentrations of additive varied from 0.125% to 5%.
 - (f) Completed.
 - (h) Master's thesis by A. Amatangelo in preparation.
- (4657) THE RESPONSE OF A DENSITY CURRENT TO A SINUSOIDAL PRESSURE PULSE.
- (b) Laboratory project.
 - (c) Dr. Charles E. Carver, Jr., Professor of Civil Engineering, Univ. of Massachusetts, Amherst, Mass. 01003.
 - (d) Experimental; basic research.
 - (e) A system of oscillatory waves is imposed on the upper layer of a two-layered system consisting of clear and saline water. The response of the interface is observed in terms of the frequency and amplitude of the imposed waves at the free surface. The amplitude of the interfacial wave is seen to increase in accordance with an inviscid theory of Stokes.
 - (h) Master's thesis by Chao-ho Sung completed.
- (4658) THE EFFECT OF HEADER GEOMETRY UPON FLUID FLOW CHARACTERISTICS IN NUCLEAR REACTORS AND HEAT EXCHANGERS.
- (b) Laboratory project.
 - (c) Prof. Joseph M. O'Byrne, Engineering Research Institute, University of Massachusetts, Amherst, Mass. 01003.
 - (d) Experimental; applied research.
 - (e) To determine the relationships between such variables as core and tube diameter, tube lattice and spacing, header height, etc., upon the individual flow per tube for a pressure vessel in which fluid is introduced through a single radial line placed at the base of the header.
 - (f) Inactive.
 - (h) "The Effects of Geometry on Fluid Flow Characteristics in Nuclear Reactors," by David Creamer, Master's thesis, 1960.
- (4914) BOILING OF WATER ON A HORIZONTAL SURFACE WITH A VARIABLE POWER INPUT.
- (b) Laboratory project supported by Research Council, Univ. of Mass.
 - (c) Prof. Joseph M. O'Byrne, Assoc. Prof. of Mechanical Engineering, Dept. of Mechanical Engineering, Univ. of Mass., Amherst, Mass. 01003.
 - (d) Experimental; basic research.
 - (e) The purpose is to determine if, by appropriate intermittent power pulses applied to a resistance ribbon, boiling heat fluxes in excess of those for steady state can be maintained. Previous tests have shown that this "overshoot" can be induced momentarily with a single step of continuous power, and this project will extend the results to account for the effect of pulses.
- (4915) BASE FLOW STUDIES FOR MASSACHUSETTS STREAMS.
- (b) Faculty Research Grant for Research Council.
 - (c) Assoc. Prof. G. R. Higgins, Univ. of Mass., Engineering Building, Amherst, Mass. 01003.
 - (d) Experimental; field and laboratory.
 - (e) This project is intended to correlate and apply data concerning minimum stream flow in Massachusetts streams to provide indices whereby base flow may be more easily predicted at sites where water resource facilities may be of public or private benefit. Runoff records of the U. S. Geological Survey, soil maps of the U. S. Soil Conservation Service, University Forestry Department cover maps, topographic maps, and any other data deemed pertinent will be used. Statistical and probability methods will be applied to these data with computer application where possible.
 - (g) Studies to date indicate very little, if any, correlation between any single factor and base flow.
 - (h) Results to date are included in a report to the Massachusetts Water Resources Commission in September, 1963.
- (5371) A PHOTOMICROSCOPIC INVESTIGATION OF NON-NEWTONIAN FLOWS AT LOW REYNOLDS NUMBERS.
- (b) David Taylor Model Basin.
 - (c) Dr. Charles E. Carver, Jr., Prof. of Civil Engrg., Univ. of Mass., Amherst, Mass. 01003.
 - (d) Experimental; basic research.
 - (e) A non-Newtonian fluid carrying a number of neutrally buoyant spheres about 0.5 micron in diameter is viewed through a lucite or glass conduit with a microscope capable of focusing within a few microns of the boundary. The motion of the particles is observed at very low Reynolds numbers. It is planned to extend the experiments to turbulent flow with the objective of arriving at a mechanism to explain the drag-reducing characteristics of non-Newtonian additives.
- (5372) INTERFACIAL TENSIONS BETWEEN MOLTEN POLYMERS.
- (b) M.S. Research.
 - (c) Mr. D. C. Chappellear, Visiting Lecturer, Dept. of Chemical Engrg., Univ. of Mass., Amherst, Mass. 01003.
 - (d) Experimental determination of a fundamental parameter by flow measurement (MS Thesis).
 - (e) It is proposed to use Tomotika's theory of capillary breakup to determine interfacial tension between two molten polymers.
 - (h) See Chappellear, American Chemical Society, Polymer Preprints, Vol. 5 #2, p. 363 (Sept. 1964) for earlier work.
- (5373) EFFICIENCY OF SPRAY AERATION.
- (b) National Institutes of Health, U. S. Public Health Service.
 - (c) Dr. Charles E. Carver, Jr., Prof. of Civil Engrg., Univ. of Mass., Amherst, Mass. 01003.
 - (d) Experimental; basic research.
 - (e) Overall oxygen transfer coefficients are measured from deaerated water droplets falling through the atmosphere as a function of drop size and drop distance. The experiments are repeated with a synthetic detergent added to the water. Transfer coefficients are also measured from fully aerated water droplets falling through a pure nitrogen atmosphere. The investigation will conclude with the measurement of oxygen transfer efficiency from a variety of types of spray nozzles.
- (5374) NON-NEWTONIAN BEHAVIOR IN SUSPENSIONS OF DEFORMABLE SPHERES.
- (b) National Science Foundation.
 - (c) Mr. D. C. Chappellear, Visiting Lecturer, Dept. of Chemical Engrg., Univ. of Mass., Amherst, Mass. 01003.
 - (d) Experimental and theoretical basic research (MS Thesis).
 - (e) A simultaneous optical and rheological study of suspensions of deformable spheres is

proposed in order to relate the orientation and deformation of the suspended particles to the non-Newtonian behavior of fluid.

(h) See Chappellear and Nicholls, Ch. E. Progress 60 45 (1964) for a review of work leading to this project.

UNIVERSITY OF MICHIGAN, Department of Civil Engrg.

(4858) WATER HAMMER: RESONANCE IN TRIPLEX PUMP SUCTION AND DISCHARGE LINES.

- (b) Union Pump Company.
- (c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
- (d) Theoretical and experimental; basic research.
- (e) Theoretical determination of resonance-free suction lines and experimental study of actual transients.

(4859) PULSATILE FLOW THROUGH ARTERIES.

- (b) National Institutes of Health.
- (c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
- (d) Theoretical and experimental; basic research.
- (e) Computer simulation of portions of the arterial tree; experimental studies of energy dissipation in pulsatile flow through distensible tubes.
- (h) "Energy Dissipation in Pulsatile Flow Through Distensible Tapered Vessels," V. L. Streeter, Chapter 8 of Pulsatile Blood Flow, E. O. Attinger, Ed., McGraw-Hill Book Co., 1964.
- "Pulsatile Flow in Cylindrical and Tapered Rubber Tubing," D. C. Wiggert and W. F. Keitzer, ASME Annual Meeting Paper 64 WA/HUF-1, 1964.

(4860) WATER HAMMER: FAILURE OF PUMPS.

- (b) National Science Foundation.
- (c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., University of Mich., Ann Arbor, Mich. 48104.
- (d) Theoretical.
- (e) Study of water hammer in suction and discharge lines of large pumping stations with multiple pumps when one or more lose their power. Dimensionless, homologous complete characteristics used with computer program for water hammer based on methods of characteristics.
- (f) Completed.
- (h) "Waterhammer Analysis of Pipelines," V. L. Streeter, Proc. ASCE, J. Hyd. Div. Paper 3974, HY4, July 1964.

(4861) WATER HAMMER, ITS EFFECT ON MINOR LOSSES.

- (b) National Science Foundation.
- (c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
- (d) Theoretical and experimental; basic research for doctoral thesis.
- (e) Investigation of effect of minor losses on water hammer pulses, the losses being developed from a series of closely-spaced orifices. Transmission and reflection coefficients obtained by theory; then programmed into a water hammer solution for the experimental set-up.
- (f) Completed.
- (g) Transmission and reflection due to a minor loss of $K V^2/2g$ each equal to $K/2 V^2/2g$.
- (h) "The Reflection of Waterhammer Pressure Waves from Minor Losses," D. N. Contractor, Winter Annual Meeting ASME Paper No. 64, WA/FE-16, 1964.

(4862) WATER HAMMER, LIQUID COLUMN SEPARATION.

- (b) National Science Foundation.
- (c) Prof. V. L. Streeter, Prof. of Hydraulics,

Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.

- (d) Theoretical and experimental; basic research for doctoral thesis.
- (e) Study of shape of separated liquid free surface in a horizontal pipe.
- (f) Experimental work completed.

(4946) RESONANCE IN PIPELINES.

- (b) Horace H. Rackham School of Graduate Studies, The University of Michigan, Ford Foundation, National Science Foundation.
- (c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
- (d) Theoretical.
- (e) Study of geometry of pipelines and the frequencies for which resonance could occur. Effect of friction in damping resonance.

(5558) THE EFFECT OF URBANIZATION ON THE RUNOFF PROCESS.

- (b) Laboratory project supported by the Horace H. Rackham School of Graduate Studies.
- (c) Dr. E. F. Brater, Prof. of Hydraulic Engineering, Dept. of Civil Engineering, Ann Arbor, Michigan 48104.
- (d) Analysis of field data, basic research.
- (e) Rainfall and runoff data from six watersheds are being analyzed. Some watersheds are rural, others are urbanized and others are in the process of urbanization. The ultimate goal of the research is the prediction of storm runoff on watersheds in various stages of urbanization.
- (g) Research is in preliminary stage.

(5559) RESONANCE IN PRESSURIZED PIPING SYSTEMS.

- (b) Laboratory project.
- (c) Dr. E. B. Wylie, Civil Engineering Dept., Univ. of Michigan, Ann Arbor, Mich. 48104.
- (d) Theoretical; basic research for doctoral thesis.
- (e) Investigation presents a method for determining the resonant characteristics of practical fluid piping systems.
- (f) Completed.
- (g) Concept of hydraulic impedance is used to determine the frequency response of a number of different types of systems. Two types of excitation are discussed, one being a forced oscillation and the second being a self-induced oscillation. Experimental verification is obtained from an analysis of data from an actual condition of resonance at a hydro-electric plant.
- (h) "Resonance in Pressurized Piping Systems," E. B. Wylie, Ph.D. dissertation, Univ. of Michigan, December 1964.

UNIVERSITY OF MICHIGAN, Ship Hydrodynamics Lab.

(5375) LARGE BULBOUS BOWS ON FULL SHIP FORMS.

- (b) Laboratory project.
- (c) Prof. R. B. Couch, Ship Hydrodynamics Lab., Univ. of Mich., Ann Arbor, Mich. 48104.
- (d) Experimental; applied research.
- (e) Investigation of the effects on resistance and on flow of large bulbous bows on a full ship hull model. Variables are size, shape and position of bulb as well as displacement and trim of the model.
- (g) Significant reductions in form and wave resistances are possible with proper combination of bulb, displacement and trim.
- (h) Internal only.

(5376) SCALE EFFECT ON RESISTANCE AND SELF-PROPULSION FACTORS OF MERCHANT SHIP FORMS.

- (b) Maritime Administration, Dept. of Commerce.
- (c) Prof. R. B. Couch, Ship Hydrodynamics Lab., Univ. of Mich., Ann Arbor, Mich. 48104.

- (d) Experimental; basic research.
 - (e) Ship models of Series 60 forms and variations and corresponding propeller models of varying size are being tested for resistance and propulsion characteristics to investigate effects of scaling. More accurate full scale predictions are sought.
 - (h) Interim report.
- (5377) BLOCKAGE CORRECTION IN A SHIP MODEL TOWING TANK.
- (b) Maritime Administration, Dept. of Commerce.
 - (c) Prof. F. C. Michelsen, Dept. of Naval Architecture and Marine Engrg., Univ. of Michigan, Ann Arbor, Michigan 48104.
 - (d) Experimental and theoretical; basic research.
 - (e) The restricted channel effect is being investigated both theoretically and experimentally, the latter by geosim series towing tests of models in The University of Michigan tank and by comparison with tests from other tanks.
 - (g) A semi-empirical formula has been developed for normal merchant ship forms and is being refined.
- (5378) DETERMINATION OF VISCOUS DRAG OF SHIP MODELS BY WAKE SURVEY.
- (b) Maritime Administration, Dept. of Commerce.
 - (c) Prof. F. C. Michelsen, Dept. of Naval Architecture and Marine Engrg., Univ. of Michigan, Ann Arbor, Michigan 48104.
 - (d) Theoretical and experimental; basic research.
 - (e) A five-hole spherical pitot tube is used to determine the wake velocity field. Momentum considerations allow calculation of the viscous drag taking into account the free surface.
 - (g) Tests under preparation.
- (5379) DEVELOPMENT OF A LOW-RESISTANCE, HIGH DISPLACEMENT-LENGTH RATIO MERCHANT HULL FORM.
- (b) Maritime Administration, Dept. of Commerce.
 - (c) Prof. F. C. Michelsen, Dept. of Naval Architecture and Marine Engrg., Univ. of Michigan, Ann Arbor, Michigan 48104.
 - (d) Theoretical and experimental; applied research.
 - (e) To develop a minimum wave resistance hull form of higher than generally designed displacement-length ratio from theoretical considerations and model tests.
 - (g) Basic model under construction.

MICHIGAN STATE UNIVERSITY, Dept. of Civil Engrg.

- (5380) DISPERSION IN FLOW THROUGH ANISOTROPIC POROUS MEDIA.
- (b) Michigan State Univ. Institute of Water Research.
 - (c) Mr. J. R. Adams, Assistant Instructor, Dept. of Civil Engrg., Michigan State Univ., East Lansing, Michigan.
 - (d) Experimental, basic research, for doctoral dissertation.
 - (e) The dispersion of tracer spots is being measured in two dimensional flow through a porous bed with anisotropic permeability. The study is an attempt to determine the macroscopic nature of dispersion in porous media.

UNIVERSITY OF MINNESOTA, Agricultural Experiment Station.

- (1929) DRAIN TILE JUNCTION LOSSES.
- Cooperative with St. Anthony Falls Hydraulic Laboratory. See page 72.
- (2350) DRAINAGE OF AGRICULTURAL LAND - DESIGN

CRITERIA.

- (b) Laboratory project.
 - (c) Dr. Curtis L. Larson, Agricultural Engrg. Dept., Univ. of Minnesota, St. Paul, Minnesota 55101.
 - (d) Field investigation; applied research.
 - (e) Continuous measurement of tile flow rates are made, mainly to determine frequency of maximum daily flows for both mineral and organic soils.
 - (h) "Tile Flow and Power Use Data for Several Pump Drainage Systems," by C. L. Larson and D. M. Manbeck. Transactions of the ASAE, Vol. 5, No. 2, 1962.
- (2576) CONSTRUCTION, DEVELOPMENT, AND PUMPING OF SHALLOW WELLS FOR IRRIGATION.
- (b) Field project.
 - (c) Prof. Evan R. Allred, Dept. of Agricultural Engineering, Univ. of Minn., St. Paul 1, Minn.
 - (d) Field investigation; applied research and development.
 - (e) The objectives of the project are: (1) To study and develop inexpensive methods for construction of shallow irrigation wells, (2) determine hydraulic permeability and characteristics of various aquifers, and (3) to survey and determine extent and availability of shallow ground water sources for irrigation in Minnesota.
- (5467) HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS.
- (b) North Central Regional Project, NC-66.
 - (c) Dr. Curtis L. Larson, Agricultural Engrg. Dept., Univ. of Minnesota, St. Paul, Minnesota 55101.
 - (d) Theoretical and experimental; basic and applied.
 - (e) Mathematical model techniques will be applied to runoff data from small watersheds.
 - (f) Active - recently initiated.

UNIVERSITY OF MISSOURI, Dept. of Civil Engineering.

- (5259) HYDRAULIC CHARACTERISTICS OF HIGHWAY GRATE INLETS.
- (b) Rowland Engineering Co.
 - (c) Dr. John J. Cassidy, Civil Engineering Dept., University of Missouri, Columbia, Mo. 65201.
 - (d) Experimental; applied.
 - (e) Several commonly used geometric types of grate inlets are being investigated in order to generalize the hydraulic characteristics of the grates, and hence provide a rational means of comparison of individual efficiencies.
 - (g) For a given combination of gutter slope, cross-slope, and geometric configuration of the grate, the efficiency has been shown to be a function of the Froude number of the approaching flow, and the dimensionless depth of flow in the gutter.
- (5260) IRRROTATIONAL FLOW THROUGH A SPILLWAY BUCKET OF GIVEN SHAPE IN A GRAVITY FIELD.
- (b) U.S. Army Corps of Engineers Waterways Experiment Station.
 - (c) Dr. John J. Cassidy, Dept. of Civil Engineering, University of Missouri, Columbia, Mo. 65201.
 - (d) Analytical; basic research.
 - (e) An analytical method is being devised for the determination of free-surface profiles, pressure distributions, and velocity distributions for irrotational flow through a curved spillway of given shape in a gravity field.
- (5261) THE CELERITY OF SOLITARY WAVES OF CONSTANT FORM.

- (b) Laboratory project.
(c) Dr. Charles Lenau, Dept. of Civil Engineering, Univ. of Missouri, Columbia, Mo. 65201.
(d) Analytical; basic.
(e) The celerity of solitary waves with large amplitudes is being investigated through numerical solution of a nonlinear integral equation under the assumption that the flow is potential. The wave of maximum amplitude is of particular interest.
- (5262) FREE-STREAMLINE FLOW UNDER A SLUICE GATE IN A GRAVITATIONAL FIELD.
(b) Laboratory project.
(c) Dr. Charles Lenau, Dept. of Civil Engrg., Univ. of Missouri, Columbia, Mo. 65201.
(d) Analytical; basic.
(e) This project was primarily concerned with the numerical difficulties usually encountered in solving a problem involving a free streamline extending to infinity under the action of gravity.
(f) Completed.
(g) Convergence of the numerical solution was improved greatly after the singularity at infinity was subtracted from the integral equation used to solve for the free-surface profile.
(h) "A Few Comments Concerning the Flow of Fluid Under a Sluice Gate in a Gravitational Field," being published as an Engineering Experiment Station Bulletin at the University of Missouri.
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- UNIVERSITY OF MISSOURI AT ROLLA, Dept. of Civil Engrg.
- (319) WEIR STUDIES.
(b) Laboratory project.
(c) Prof. E. W. Carlton, Civil Engrg. Dept., University of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Tests on rectangular weirs were made to determine effect of velocity of approach on the relation between crest depth and critical depth of an imaginary open channel having same dimensions as the weir opening.
(g) Study produced a simple, accurate and quick solution for plotting of M function. Relationship between the M function, and the critical depth is logarithmic. This greatly simplifies determination of critical flow where the critical depth is known or vice versa. A relationship exists between M function of channels of same shape but different dimensions. The velocity of approach does not affect the relationship between physical depth and crest depth.
- (3775) VERTICAL WATER JET IMPACTING UPON A STILLING BASIN.
(b) Laboratory project.
(c) Prof. V. A. C. Gevecker, Civil Engineering Department, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Tests being conducted on the terminal effect of a 3/8 inch water jet on a cylindrical stilling basin to determine side and bottom pressures, velocities and energy dissipated.
- (4169) INVESTIGATION OF VERTICAL INTERNAL SPILLWAYS.
(b) Laboratory project.
(c) Prof. C. D. Muir, Assoc. Prof. of Civil Engineering, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) A scale model rockfill dam containing a vertical internal spillway was studied to determine factors affecting stage-discharge relationships.
(g) A correlation was found to exist between discharge through the dam and height of spillway, rock size, and head.
(h) "Investigation of Vertical Internal Spillways," by Paul R. Munger, Master's Thesis, Missouri School of Mines, 1961. (Available on loan).
- (4661) A COMPUTER STUDY OF BACKWATER COMPUTATIONS.
(b) Laboratory project.
(c) Prof. C. D. Muir, Associate Professor of Civil Engineering, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) The effect of some approximations used in backwater calculations on the resulting surface profile were studied by use of a digital computer. Also, several methods of backwater computations were compared.
(g) The results of this study indicated that the use of approximations is feasible for curves above critical depth but are dependent on flow regime.
(h) "A Comparison of Backwater Profile Computations," by A. C. H. Young, Master's Thesis, Missouri School of Mines, 1962. (Available on loan).
- (4662) HYDROLOGY OF SMALL MISSOURI WATERSHEDS.
(b) Laboratory project.
(c) Prof. C. D. Muir, Associate Professor of Civil Engineering, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) This study was for the purpose of correlating basin characteristics and mean annual flood for Missouri watersheds having a drainage area of less than ten square miles.
(f) Suspended.
(g) It was found that mean annual floods could be predicted and correlated to known data from forty-five Missouri watersheds by use of a shape factor (AL^2) and basin index ($AL^2S^{1/2}$).
(h) "A Study of Small Watersheds Within the State of Missouri," by Terrence E. Harbaugh, Master's Thesis, Missouri School of Mines, 1962. (Available on loan).
- (4663) FLOW THROUGH A ROCKFILL DAM.
(b) Laboratory project.
(c) Prof. P. R. Munger, Assistant Professor of Civil Engineering, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Model studies are being conducted on a rockfill dam with a sloping internal spillway to determine the characteristics of flow through such dams.
(g) Preliminary results indicate a relation exists between flow rate, head, core height and rock size.
(h) "Investigation of Flow Rates Through a Rock-fill Dam," by J. R. Bayless, Master's thesis, Missouri School of Mines and Metallurgy, 1962.
- (5468) INVESTIGATION OF HIGH VELOCITY JETS ON HYDRAULIC JUMP.
(b) Laboratory project.
(c) Prof. Paul R. Munger, Dept. of Civil Engrg., Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Investigation of tailwater depth, length, and wave formation properties of hydraulic jump due to introduction of high velocity jets from apron.

(5469) VELOCITY AND KINETIC ENERGY DISTRIBUTION OF A SUBMERGED JET.

- (b) Laboratory project.
- (c) Prof. V. A. C. Gevecker, Dept. of Civil Engrg., Univ. of Missouri at Rolla, Rolla, Mo. 65401.
- (d) Experimental; basic research for master's thesis.
- (e) Tests conducted to determine the effect on velocity and kinetic energy by submerging a jet below the surface of a stilling basin.
- (g) The entraining effect of the submerged jet is of an order of ten or more times the discharge of the jet itself at the section of the jet opening. The major energy dissipation effects occur in the region of the jet itself. The kinetic energy decreases not linearly but exponentially with depth of penetration.
- (h) "Velocity and Kinetic Energy Distribution of a Submerged Jet", by Patrick S. Couch, Master's thesis, Missouri School of Mines and Metallurgy, 1964. (Available on loan).

MONTANA STATE COLLEGE, Agricultural Experiment Station.

(4664) EFFICIENT APPLICATION OF IRRIGATION WATER BY SURFACE FLOODING METHODS.

- (b) Laboratory project.
- (c) Prof. C. C. Bowman, Head, Agricultural Engineering Dept. Montana State College, Bozeman, Montana 59715.
- (d) This is a study to develop design criteria for more efficient application of irrigation water by flooding method. This is basic research at the present time, but will be applied research immediately upon completion of the first phase.
- (h) "Dimensional Analysis Leading to More Efficient Application of Irrigation Water", C. C. Bowman, presented at 1963 Winter Meeting of ASAE.

UNIVERSITY OF NEBRASKA, Hydrodynamics Laboratory, Dept. of Engineering Mechanics.

(3776) VORTEX FORMATION AND DRAG IN UNSTEADY FLOW PAST BLUFF BODIES.

- (b) National Science Foundation.
- (c) Prof. T. Sarpkaya, Dept. of Engineering Mechanics, Bancroft Hall 219, University of Nebraska, Lincoln 8, Nebraska.
- (d) Experimental and theoretical study of drag and inertia in unsteady flow. Basic research for master's and Ph.D. thesis.
- (e) Primary objects of the research are: To determine the growth and motion of vortices behind two dimensional bluff bodies subjected to unidirectional unsteady flow; to determine the various components of corresponding resistance; and to correlate a particular vortex configuration with the instantaneous resistance.
- (g) The forces predicted on the basis of the moving and growing vortices are comparable in magnitude to forces which are observed. Resistance to unsteady flow is not to be thought of as a mere juxtaposition of resistances to steady flow augmented by an inertial force.

(3780) MECHANISM OF TURBULENCE GENERATION IN PULSATING VISCOUS FLOW.

- (b) Office of Ordnance Research, U. S. Dept of the Army, (Durham).
- (c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln 8, Nebr.
- (d) Experimental and theoretical basic research for master's and Ph.D. thesis.
- (e) To understand the mechanism of turbulence generation in pulsating viscous flow superposed on a steady and initially laminar flow and to evaluate the resistance to fluid motion.

- (g) The evolution in time of artificially generated turbulent plugs was monitored simultaneously at several locations along the conduit by means of differential transducers. It was found that in oscillating Poiseuille flow the transition Reynolds number is determined uniquely by the parameters ka (frequency parameter) and λ (the ratio of the amplitude of the periodic component of the cross-sectional mean velocity to the steady component of the cross-sectional mean velocity), and that for the same mean pressure gradient the pulsating flow is more stable than the corresponding steady Poiseuille flow. It was further found that the transition Reynolds number decreases with increasing values of the frequency parameter ka .
- (h) "Mechanism of Turbulence Generation in Pulsating Viscous Flow", by T. Sarpkaya, Technical Report No. 012-TS, AROD No. 3202E, DDC, Cameron Station, Alexandria, Va. 22314.

(3782) INDUCED MASS OF CONFINED FLUIDS.

- (b) Laboratory project.
- (c) Prof. T. Sarpkaya, Bancroft Hall 219, University of Nebraska, Lincoln 8, Nebr.
- (d) Theoretical basic research; for master's thesis.
- (e) When a confined fluid is suddenly accelerated through an opening, initial average acceleration is determined by the induced mass of the fluid system. Since the equation of the elastic wave propagation cannot be solved for the boundary conditions imposed, solution of Laplace's equation is joined to that obtained from the wave equation through the application of the Schwartz-Christoffel transformation and electrical analogy.
- (g) The effect of induced mass is most pronounced particularly for short conduits. Average times necessary for the reflection of an elastic wave from a given reservoir is determined.

(4170) VIRTUAL MASS OF PARTLY SUBMERGED BODIES.

- (b) Laboratory project.
- (c) Prof. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln 8, Nebr.
- (d) Experimental and theoretical basic research.
- (e) Study of the added mass of various objects partly submerged in a liquid.

(4893) COUNTER VORTEX OSCILLATOR.

- (b) Diamond Ordnance Fuze Laboratories, Wash., D.C.
- (c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln 8, Nebraska.
- (d) Theoretical and experimental and for master's thesis.
- (e) To determine the intensity of pressure fluctuations and frequency of the instability created by two vortices rotating in opposite directions in two vortex chambers connected by a circular tube.
- (g) Frequency and intensity of pressure fluctuations are determined as a function of fluid properties and the geometry of the system. The counter vortex oscillator unit proved to be usable together with a pneumatic amplifier in controlling the momentum of the power jet.
- (h) Internal Report No. 1 to Diamond Ordnance Fuze Laboratories, August 1963, IR-No. 2, August, 1964.
"Characteristics of a Counter Vortex Oscillator", by T. Sarpkaya, Proceedings of the Fluid Amplification Symposium, HDL, Vol. II, May, 1964.

(4894) BISTABLE VORTEX OSCILLATOR.

- (b) Laboratory project partly supported by DOFL.
- (c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln 8, Nebraska.
- (d) Theoretical and experimental for master's thesis.
- (e) To use the vortex shedding behind a circular cylinder placed between two parallel walls

to activate a high frequency oscillator. The units built have variable frequency and push-pull characteristics.

- (g) Vortex shedding behind circular cylinders appears to be a powerful means of switching "on" or "off" the load of a pneumatic amplifier.

(5263) VORTEX-RATE SENSOR.

- (b) Harry Diamond Laboratories.
- (c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln 8, Nebraska.
- (d) Theoretical and experimental for M. S. thesis.
- (e) To use the vortex-sink flow to provide a signal proportional to rate of rotation.
- (g) Boundary layer development in vortex-sink flow has been analyzed theoretically. The units built provide sufficiently large signals for very low rates of rotation.

(5264) SEPARATED FLOW ABOUT LIFTING BODIES.

- (b) Laboratory project partly supported by NSF and ONR.
- (c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln 8, Nebraska.
- (d) Experimental and theoretical.
- (e) Cross-flow drag and normal-force coefficients are determined for slender bodies at high angles of attack within subsonic to moderately supersonic range.
- (g) Cross-flow drag coefficient is about 25% larger near the point of separation than that for steady flow at the same Reynolds number past a circular cylinder. Results indicate that Schwabe's data for cylinders set in motion impulsively from rest may be in error.

(5265) DYNAMICS OF A BISTABLE FLUID AMPLIFIER WITH A LATCHING VORTEX.

- (b) Harry Diamond Laboratories, Washington, D. C.
- (c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln 8, Nebraska.
- (d) Theoretical and experimental, M. S. thesis.
- (e) To determine the response of a bistable fluid amplifier with a latching vortex to various types of input.
- (g) Latching vortex increases the power and pressure-recovery factors but it also increases the noise level of the amplifier.

NEW YORK UNIVERSITY, Department of Chemical Engrg.

(5560) THEORETICAL STUDY OF SUSPENSION VISCOSITY: BY MEANS OF A MODEL OF THE SLOW MOTION OF SPHERES AND A VISCOUS FLUID THROUGH A CYLINDER.

- (b) Laboratory project.
- (c) Prof. J. Happel, Dept. of Chem. Engrg., New York Univ., Univ. Heights, Bronx, N. Y. 10453.
- (d) Theoretical; basic research for doctoral thesis.
- (e) The slow translational and rotational motion of particles moving through a viscous fluid subjected to the influence of cylindrical boundaries is being studied. This will ultimately enable a theoretical prediction of the frictional drag, rotational moment, permanent pressure drop caused by the presence of these particles in the original Poiseuilleian field of flow, and suspension viscosity.
- (g) The method of reflections technique for solving boundary value problems is applied to the slow translational and rotational motion of a particle subjected to the influence of cylindrical boundaries. Expressions were obtained for the frictional drag, rotational moment, permanent pressure drop and suspension viscosity.

NEW YORK UNIVERSITY, Department of Meteorology and Oceanography.

(3120) OFFICE OF NAVAL RESEARCH ATMOSPHERE INTERACTION AND WAVE PROJECT.

- (b) Geophysics Branch, Office of Naval Research, Department of the Navy.
- (c) Prof. Gerhard Neumann, Prof. of Oceanography and Prof. Willard J. Pierson, Prof. of Oceanography, New York University, New York 53, New York.
- (d) Experimental and theoretical; basic and applied research.
- (e) Study of wave generation and propagation in deep water; nonlinear properties of capillary and gravity waves in both Eulerian and Lagrangian form. Observations of temperature, humidity, and wind over the sea surface. Albedo measurements. Wind stress over the water surface. The prediction of large scale oceanic circulations. Theoretical and observational studies of turbulence in water. Diffusion studies.
- (g) Models of random seas in Lagrangian form have been developed that look promising. Field work has been expanded by the acquisition of a T-boat and additional scientific equipment. Dye studies in Long Island Sound and adjacent waters. Studies of the circulation of western boundary currents. A thesis on the stratification and circulation of the Brazil Current has been completed. The Equatorial Undercurrent in the Atlantic Ocean and the stratification of water masses in the tropical Atlantic.
- (h) "Notes on the Theory of the Thermocline," by R. Blandford, J. Mar. Res.
- "Inertial Flow in the Gulf Stream," by R. Blandford. Tellus.
- "The Use of Rayleigh-Ritz Method for Calculating the Eddy Viscosity," by A. D. Kirwan. Proc. of the Conference at Lamont Observatory.
- "Oceanography of the Tropical Atlantic," by G. Neumann. Annals of the Symposium on the Oceanography of the Western South Atlantic.
- "Observations of the Equatorial Undercurrent in the Atlantic at 15° W during Equalant I," by G. Neumann and R. G. Williams. J. Geophys. Res.
- "Third Order Steady State Solutions for Intersecting Trains of Gravity Waves," by W. J. Pierson. Tech. Rept. GSL 64-3, Dept. of Meteor. and Ocean., New York University.
- "Known and Unknown Properties of the Two-Dimensional Wave Spectrum and Attempts to Forecast the Two-Dimensional Wave Spectrum for the North Atlantic Ocean," by W. J. Pierson. Fifth Symposium on Naval Hydrodynamics, Sept. 10 through 12, 1964.
- "Problem Areas in Ship Motion Research," by W. J. Pierson. Proc. Fifth Symposium on Naval Hydrodynamics, Sept. 10 through 12, 1964.
- "Near Surface Oceanic Diffusion From a Continuous Point Source," by R. Reinert. J. Oceanographical Society of Japan.
- (5470) WAVE HINDCASTING PROJECT.
- (b) U. S. Naval Oceanographic Office.
- (c) Prof. Willard J. Pierson, Prof. of Oceanography, and Dr. Leo J. Tick, New York Univ., Bronx 53, N. Y.
- (d) Experimental and theoretical, basic and applied.
- (e) To forecast the directional spectrum of waves over the North Atlantic Ocean by means of a computer.
- (g) New results on the spectra of wind seas and on forecasting waves have been obtained and will be reported during the next year.
- (h) "Wave Spectra Estimated from Wave Records Obtained by the OWS Weather Explorer and the OWS Weather Reporter," (I) and (II), by L. Moskowitz, W. J. Pierson, and E. Mehr.
- "Estimates of the Power Spectrums for Fully Developed Seas for Wind Speeds of 20 to 40 Knots," by L. Moskowitz. J. Geophys. Res., Dec. 1964.
- "A Proposed Spectral Form for Fully Developed Wind Seas Based on the Similarity Theory of

S. A. Kitaigorodskii," by W. J. Pierson and L. Moskowitz. J. Geophys. Res., Dec. 1964. "The Interpretation of Wave Spectrums in Terms of the Wind Profile Instead of the Wind Measured at a Constant Height," by W. J. Pierson. J. Geophys. Res., Dec. 1964.

NEW YORK UNIVERSITY, School of Engineering and Science, Department of Civil Engineering.

(4988) MECHANISM OF GAS ABSORPTION BY TURBULENT LIQUIDS.

- (b) Laboratory project.
- (c) Dr. William E. Dobbins, Prof. of Civil Engineering, New York University, School of Engineering and Science, University Heights, Bronx, New York 10453.
- (d) Theoretical and experimental; basic research (doctoral thesis).
- (e) A study of the mechanism by which gases are transferred across a turbulent gas-liquid interface, with particular emphasis on the process as it occurs in natural streams.
- (g) A mathematical model for the transfer process has been developed. Experimental work using several gases of varying diffusivities indicates an acceptability of the mathematical model. The present phase is concerned with the effect of impurities in the liquid.
- (h) "Mechanism of Gas Absorption by Turbulent Liquids," by William E. Dobbins, Advances in Water Pollution Research, Volume 2, Pergamon Press, 1964, p. 61. Reprint available upon request. "BOD and Oxygen Relationships in Streams," Proc. A.S.C.E., SA3, p. 53, June, 1964.

NORTH CAROLINA STATE OF THE UNIVERSITY OF NORTH CAROLINA, Department of Engineering Research.

(4667) UNSTEADY FREE SURFACE FLOWS.

- (b) Laboratory project.
- (c) Dr. M. Amein, Department of Civil Engrg., North Carolina State of the Univ. of No. Carolina, Raleigh, N. C.
- (d) Experimental and theoretical; basic research.
- (e) An experimental investigation on translatory motions with irregular profiles, on bore formations and on the propagation of unsteady motions through non-uniform flows is made in a glass-walled channel. The channel is 14 ft. long, 2 ft. wide with adjustable variable slope. The experimental results are analyzed by the nonlinear shallow water theory. The objective of the project is to seek improvements to the prevalent techniques for the computation of unsteady flows and to provide experimental data for further theoretical investigations.

(4668) STUDY OF VORTEX MOTION IN WAKE FLOWS.

- (b) Laboratory project.
- (c) Prof. Paul Harrawood, Department of Civil Engineering, North Carolina State of the Univ. of No. Carolina, Raleigh, North Carolina.
- (d) Experimental and theoretical; doctoral thesis.
- (e) An investigation of the eddy motions present in the wakes of bluff bodies in a streaming fluid, with particular attention given to the periodicity of eddy motions and to vortex strength.

(4669) AN INVESTIGATION OF THE STABILITY OF FLOW IN CIRCULAR SEDIMENTATION BASINS.

- (b) Laboratory project.
- (c) Professor Charles Smallwood, Jr., Dept. of Civil Engrg., North Carolina State of the Univ. of No. Carolina, Raleigh, North Carolina.
- (d) Experimental; master's thesis.

- (e) A semi-circular center-fed model basin was built with a transparent back for visual examination of the flow pattern. A uranine dye tracer was used to determine flow through waves for the basin. Stability was measured by the reproducibility of the time-effluent dye concentration waves. In an attempt to stabilize the flow radial baffles were placed in the basin to reduce the angle of divergence and to provide solid boundaries in the divergent flow.
- (f) Completed.
- (g) The baffles had no detectable effect. The flow pattern was characterized by a short-circuit along the tank bottom and a back-flow in the upper portion of the tank.

NORTH DAKOTA STATE UNIVERSITY, Agricultural Engrg. Dept.

(3121) PREFABRICATED DITCH LININGS.

- (b) Laboratory project.
- (c) Prof. Harold Holmen, Assistant Agricultural Engineer, Agricultural Engineering Dept., North Dakota State University, Fargo, N. Dak.
- (d) Experimental; applied research.
- (e) Seepage tests were made on buried 6 mil and 10 mil black polyethylene linings that have been in place for a period of 4 years.
- (f) Completed.
- (g) Black polyethylene linings buried under a soil cover remained in excellent condition after 4 years of service.

(3475) SURFACE DRAINAGE.

- (b) Laboratory project.
- (c) Prof. Harold Holmen, Assistant Agricultural Engineer, Agricultural Engineering Dept., North Dakota State University, Fargo, N. Dak.
- (d) Field investigation; applied research.
- (e) A small amount of work on ditch maintenance was performed in 1964.

(4175) WATER INTAKE RATES AND PHYSIOCHEMICAL PROPERTIES OF IRRIGABLE SOILS.

- (b) Joint laboratory project between Department of Agricultural Engineering and Department of Soils.
- (c) Prof. Harold Holmen, Assistant Agricultural Engineer, Agricultural Engineering Dept., North Dakota State University, Fargo, N. Dak.
- (d) Experimental, basic research, and Master's thesis.
- (e) Infiltration tests were made in the field comparing large (up to 38 inches) infiltration rings with smaller rings (up to 22 inches in diameter). Infiltration rates on land seeded to barley was compared with infiltration on summerfallow.
- (g) Infiltration rates obtained using the large rings were significantly greater than rates obtained using the smaller rings. Infiltration rates were higher on the barley than on the summerfallow land. Antecedent moisture conditions accounted for most of the difference.
- (h) "Infiltration of Water into Potentially Irrigable Soils", H. Holmen, J. M. Schaack, and R. I. Strand. North Dakota Farm Research, Vol. 23, No. 5, pp. 16-19, May-June 1964. "Soil Structure Stability Under Irrigation", G. E. Wilkinson, and F. Schroer. North Dakota Farm Research, Vol. 23, No. 5, pp. 19-21, May-June 1964.

(5471) CONCRETE DITCH LINING AND PIPE FOR IRRIGATION SYSTEMS.

- (b) Laboratory project.
- (c) Prof. Harold Holmen, Assistant Agricultural Engineer, Agricultural Engineering Dept., North Dakota State Univ., Fargo, N. Dak.
- (d) Experimental; applied research and Master's thesis.

- (e) Six hundred feet of arm distribution ditch was lined with concrete applied with a slip-form machine. Nearly 1800 feet of 12 inch low pressure concrete pipe with 6 inch risers was installed to replace another farm ditch. These installations will be used to study the economic features of lined and closed conduit distribution systems; and to study the potential life of the installation, especially with regard to frost action and damage from farm machinery traffic.
- (g) The installation was made in September of 1964 and various initial measurements have been taken.

NORTHWESTERN UNIVERSITY, The Technological Institute.

(3476) FLOOD WAVE ROUTING.

- (b) Northwestern Technological Institute.
- (c) Prof. W. S. Hamilton, Dept. of Civil Engrg., Northwestern University, Evanston, Ill. 60201.
- (d) Theoretical and analytical for doctoral and masters theses.
- (e) The purpose is to calculate the movement of flood waves in prismatic and natural channels. Finite difference equations based on (a) method of characteristics and (b) basic equations of momentum and continuity are to be programmed separately for solution on a digital computer.
- (g) A backward difference method of handling the basic equations was unstable. A marching procedure using the method of characteristics gives promise. Errors in the computer program have not yet been eliminated.

(3799) FORCES ON SUBMERGED BODIES IN UNSTEADY MOTION.

- (b) Laboratory project.
- (c) Professor Lyle F. Mockros, Dept. of Civil Engineering, Northwestern University, Evanston, Illinois 60201.
- (d) Theoretical and experimental, basic research, M. S. and Ph.D. theses.
- (e) Investigation of the forces on solid spheres accelerating along a rectilinear path through incompressible viscous fluids. The investigation includes (1) experiments that will be compared with a numerical evaluation of theoretical linear solutions, (2) experiments on the general case of large motions, and (3) a study of the effect of the velocity pattern on added mass.
- (g) The complex theoretical solution for the creeping motion case has been put into graphical form. Experiments on large motion oscillations have been performed and the data correlated in terms of velocity (drag), acceleration (added mass) and history coefficients.
- (h) "Forces on a Sphere Accelerating in a Viscous Fluid", F. Odar and W. S. Hamilton, Journal of Fluid Mechanics, Vol. 18, pp. 302-314, 1964.

4671) VISCOELECTRIC MAGNETOHYDRODYNAMIC FLOW ANALOG.

- (b) Laboratory project.
- (c) Mr. Thomas P. Anderson, Assoc. Prof., Dept. of Mech. Engineering and Astronautical Sciences, Northwestern University, Evanston, Illinois 60201.
- (d) Thesis research relating to the flow of viscoelectric fluids.
- (e) The analogy between magnetohydrodynamic Hartmann flow and the flow of a viscoelectric fluid between parallel plates is being investigated. The Winslow effect provides a variable viscosity under the influence of an applied electric field and these Winslow forces may be tailored to create a force field equivalent to the Lorentz force field in a magnetohydrodynamic flow.
- (g) Velocity profiles and pressure drops in the viscoelectric flow have been measured

- experimentally and agree closely with those predicted by the magnetohydrodynamic theory.
- (h) "Viscoelectric Magnetohydrodynamic Analogy", T. P. Anderson, Amu-ANL Conference on Direct Energy Conversion, Argonne National Laboratory Report ANL-6802, Dec. 1963, pp. 37-39.

(5032) WAVE ENERGY DISSIPATION.

- (b) Northwestern Technological Institute.
- (c) Prof. W. S. Hamilton, Dept. of Civil Engrg., Northwestern Univ., Evanston, Illinois 60201.
- (d) Theoretical and experimental for theses.
- (e) The purpose is to obtain useful expressions for the velocity profiles and shear profiles in the boundary layer next to a wall along which deep-water oscillatory waves are progressing, to obtain a criterion for transition from laminar to turbulent motion, and to measure the velocity profiles near the wall.
- (g) The work involving laminar boundary layers has been reviewed and expanded. The equations of motion have been integrated for an assumed form of the Reynolds stress. Coefficients in the result need to be evaluated experimentally.
- (h) "Boundary Layers Caused by Water Waves in a Rectangular Channel", Ph.D. Thesis, A. Santiago, June 1964.

(5472) WIND-DRIVEN CIRCULATION IN LAKE MICHIGAN.

- (b) National Science Foundation.
- (c) Asst. Professor G. E. Birchfield, Dept. of Civil Engineering, Northwestern Univ., Evanston, Ill. 60201.
- (d) Two year grant, theoretical study; funds for research assistant, undergraduate assistant; primarily basic research.
- (e) Develop mathematical methods for predicting response of lake to varying wind conditions. Study forces which generate lake currents, effect of shore lines on currents. Together with recent observational studies, construct better picture of general circulation in lake, than at present.
- (f) Initiated October 15, 1964.
- (g) Preliminary results are available for some simple analytical models of wind-driven circulations.

(5473) DYNAMIC FLOW CHARACTERISTICS OF VENTRICLE PUMPS.

- (b) Bio-Medical Engineering Center, Northwestern Technological Institute.
- (c) Prof. Lyle F. Mockros, Dept. of Civil Engrg., Northwestern Univ., Evanston, Illinois 60201.
- (d) Experimental and theoretical; basic and applied research, M.S. Thesis.
- (e) Investigation of the dynamics of pumping fluid out of a flexible chamber by pneumatically squeezing the chamber.

(5474) PHYSICAL ENVIRONMENT OF EXTRACORPOREAL CIRCULATION.

- (b) Bio-Medical Engineering Center, Northwestern Technological Institute.
- (c) Prof. Lyle F. Mockros, Dept. of Civil Engrg., Northwestern Univ., Evanston, Illinois 60201.
- (d) Experimental; basic and applied research, Ph.D. thesis.
- (e) Investigation of the geometry and fluid dynamics favorable to the circulation of blood outside the animal body. Purpose is to obtain design criteria for heart lung machines.

(5475) NOISE SPECTRA GENERATED BY FLOW OF A LIQUID THROUGH VARIOUS ORIFICES.

- (b) Bio-Medical Engineering Center, Northwestern Technological Institute.
- (c) Prof. W. S. Hamilton, Dept. of Civil

Engrg., Northwestern Univ., Evanston, Illinois 60201.

- (d) Experimental; applied research, thesis.
- (e) Purpose is to identify characteristic flow generated noise in an abnormal heart. The noise spectra generated by steady and pulsating flow through rigid and flexible orifices is being investigated.
- (g) The noise spectra for steady flow through orifices as reported in the literature has been verified for water flows.

OHIO AGRICULTURAL EXPERIMENT STATION, Department of Agricultural Engineering

(5033) DRAINAGE INVESTIGATIONS FOR AGRICULTURAL LANDS.

- (b) Ohio Agricultural Experiment Station in cooperation with the Agricultural Research Service.
- (c) Mr. G. O. Schwab, 2073 Neil Ave., The Ohio State University, Columbus, Ohio 43210.
- (d) Field investigation; applied research.
- (e) Tile flow, surface runoff, water table levels, and crop yields are measured to evaluate various types of drainage systems and to develop improved engineering design criteria.
- (g) Fourteen years of tile flow data, partial analysis completed; corn yields measured for three years from various methods of drainage.
- (h) "Spacing Tile Drains", G. O. Schwab. Ohio Farm and Home Research 49:6-7, 11, Jan.-Feb. 1964.

(5293) FLOW OF COLLOIDAL SUSPENSIONS IN POROUS MEDIA.

- (b) Laboratory project with partial support by National Science Foundation.
- (c) Prof. R. Bruce Curry, Assoc. Prof. Dept. of Agricultural Engineering, Ohio Agricultural Experiment Station, Wooster, Ohio 44691.
- (d) Theoretical and experimental; basic research.
- (e) To investigate the fundamental principles underlying the flow of colloidal suspensions into or through porous media. The scope of this study will include the use of several granular materials and suspensions of colloidal materials. Initially, carborundum will be used as the porous media and Wyoming bentonite as the suspended material in order that there will be continuity between the present work and past studies. Materials to be used later will include chemically active materials such as zeolite, natural occurring materials, such as soils and filter sands. The natural occurring materials will be used to tie this basic study to practical applications in the field. Both the porous media and the suspended materials will be characterized completely by determination of various physical and chemical properties. The granular material will be placed in a permeameter for testing. The actual test procedure will involve three phases: (1) Initial flow of de-aired; de-ionized water through the porous media in the permeameter; (2) followed by the introduction of the suspension into the permeameter; (3) finally the de-aired, de-ionized water will be reintroduced into the permeameter in order to determine the effect of the suspension flow on the system.
- (h) "Effect of Viscosity and Zeta Potential of Bentonite Suspensions on Flow Through Porous Media," D. L. Rausch and R. B. Curry, Trans. ASAE, Vol. 6, p. 167-9, 1963 (reprints available from junior author). "The Interrelationships of Physical and Chemical Properties Involved in the Flow of Colloidal Suspensions in Porous Media," by R. B. Curry, G. L. Barker and Z. Strach. 1964 ASAE Paper No. 64-217 (available from

ASAE, St. Joseph, Michigan). "Scandium as a Tracer of the Movement of Clay Suspensions in Columns of Porous Media," by R. Bruce Curry, 1964, ASAE Paper No. 64-622 (available from ASAE, St. Joseph, Michigan).

(5294) HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS.

- (b) Laboratory project.
- (c) Prof. R. Bruce Curry, Assoc. Prof. Dept. of Agricultural Engineering, Ohio Agricultural Experiment Station, Wooster, Ohio 44691.
- (d) Theoretical; basic research.
- (e) To investigate the use of mathematical, electrical, and hydraulic models to study hydrologic phenomena of watersheds. (a) To investigate statistical models as a means of identifying and evaluating the pertinent variables in the runoff process. (b) To use these variables together with a mathematical model to predict behavior of a small watershed. The behavior of small watersheds will be investigated to identify the pertinent variables using the statistical theory. These variables will be combined with the underlying physical and biological phenomena to develop a mathematical model which will permit statements to be made about probable watershed behavior. Data from existing watersheds and runoff plots will be used to test the validity of the model.

OHIO AGRICULTURAL EXPERIMENT STATION, Department of Agronomy.

(5176) SOIL CHARACTERISTICS AND SUBSURFACE DRAINAGE.

- (b) Ohio Agricultural Experiment Station.
- (c) Prof. George S. Taylor, Dept. of Agronomy, Ohio State Univ., Columbus, Ohio 43210.
- (d) Experimental investigation, applied research.
- (e) Numerical analysis solutions of soil moisture flow problems in subsurface drainage are made with digital computers. Steady-state and transient analyses are studied for various parameters of size, depth, and spacing of tile and ditch drains and of soil hydraulic conductivity. Hillside seepage problems are also evaluated. The principal objective is to interrelate the above factors in rational design of subsurface drainage systems.
- (g) Characteristics of water flow into tile drains have been studied for layered soils. An analysis of hillside seepage into open ditches was made. Agreement between analytical and numerical analysis techniques was established.

OKLAHOMA STATE UNIVERSITY, Agricultural Engineering Department.

(2365) HYDROLOGIC STUDIES ON SMALL GRASS-COVERED WATERSHEDS.

- (b) Oklahoma Agricultural Experiment Station, cooperative with Agricultural Research Service, U. S. Dept. of Agriculture.
- (c) Prof. P. R. Crow, Okla. State Univ., Dept. of Agricultural Engrg., Stillwater, Okla. 74075.
- (d) Field investigation; applied research.
- (e) Measurements are being made to provide hydrologic data on total watershed runoff and peak rates of runoff from three small grass-covered watersheds (17 to 206 acres) in north central Oklahoma. Highway culverts, modified by the addition of weir sills, are being used as runoff measuring devices.
- (g) Thirteen year record of rainfall and runoff record is available. Frequency distributions of runoff rates and amounts have been determined. An analysis of the effect of stock water ponds on total water yield of small watersheds has been completed.

- (h) "Determining the Effects of Farm Ponds on Runoff From Small Watersheds" by F. R. Crow and W. O. Ree. Bulletin B-629, October, 1964.
- (2828) THE EFFECTIVENESS OF MONOMOLECULAR FILMS FOR REDUCING EVAPORATION FROM RESERVOIRS.
- (b) Oklahoma Agricultural Experiment Station, cooperative with U. S. Bureau of Reclamation.
- (c) Prof. F. R. Crow, Oklahoma State Univ., Dept. of Agricultural Engineering, Stillwater, Oklahoma 74075.
- (d) Experimental; applied research.
- (e) Two paired plastic lined ponds, designed for evaporation research, are being used to study various aspects of evaporation reduction by monomolecular films. Apparatus has been developed for automatic application of hexaoctadecanol slurry. Present research is on the effects of wind on monolayers and development and testing of methods of alleviating adverse effects of wind.
- (g) Evaporation reductions of 25 to 40% have been obtained in long duration tests using slurry method of applying films. Curves have been developed relating wind speed and required film application rate. In current research a system of floating barriers is used to confine the monolayer to reduce frequency of application. Various height/spacing ratios have been tested. The effect of the barriers, with and without monolayer, on evaporation is being studied.
- (h) "Wind-Effects on Chemicals for Reducing Evaporation From Small Reservoirs," by F. R. Crow. Processed Series P-477, May 1964.
- (3804) THE HYDRAULICS OF CONSERVATION CHANNELS.
- (b) Agricultural Research Service, U.S. Dept. of Agriculture in cooperation with the Oklahoma Agricultural Experiment Station.
- (c) Mr. W. O. Ree, Agr. Research Service, Soil and Water Conservation Research Div. Southern Plains Branch, Stillwater, Okla. 74075.
- (d) Experimental; applied research.
- (e) Vegetation lined waterways of the kind used to convey short duration flood flows from small watersheds are constructed full size on the grounds of an outdoor hydraulic laboratory. Flow tests are made on these experimental channels to determine the protective ability of various grasses and to evaluate the flow friction factors under different conditions of growth. Perennial and annual grasses for the temporary protection of newly constructed earth waterways are both considered in these studies. Temporary liners of various fibers including jute, paper and glass are also tested.
- (g) Manning's n values have been determined for various grass species. The physical characteristics of the vegetation and the flow character both influence the flow retardance factor so special design diagrams have been prepared to aid in solving flow problems under these conditions.
- (4676) THE HYDRAULICS OF OVERLAND FLOW.
- (b) Oklahoma Agricultural Experiment Station cooperative with Agricultural Research Service, U. S. Dept. of Agriculture.
- (c) Dr. J. E. Garton, Oklahoma State Univ., Dept. of Agricultural Engineering, Stillwater, Okla. 74075.
- (d) Experimental; applied research.
- (e) A study of the basic relationships involved in the hydraulics of overland flow. Test channels 96 ft. long, 3 ft. wide, and 5 percent slope are subjected to simulated rainfall of various intensities and droplet sizes. Water surface profiles are studied for transient and equilibrium states for concrete lined channels with three conditions of roughness.
- (h) "Overland Flow Over Steep Rough Surfaces", M. S. Thesis, Oklahoma State Univ., May, 1964.
- "Runoff From Impervious Surfaces Under Conditions of Simulated Rainfall" by A. F. Robertson, A. K. Turner, F. R. Crow, and W. O. Ree. Paper No. 64-222 presented at 1964 Annual Meeting of the ASAE, Ft. Collins, Colorado.
- (5177) AUTOMATION OF CUT-BACK FURROW IRRIGATION.
- (b) Oklahoma Agricultural Experiment Station.
- (c) Dr. James E. Garton, Oklahoma State Univ., Dept. of Agricultural Engineering, Stillwater, Okla. 74075.
- (d) Experimental and field investigation; applied research and design for thesis.
- (e) The development of a system of cut-back furrow irrigation using level furrow outlet tubes with hooded inlets. The system will irrigate through the furrows at a design initial flow, cut-back to a design cut-back flow, and shut off by the simple removal of sheet-metal check dams. The purpose of the method is to improve the uniformity of furrow irrigation and to drastically reduce the high labor requirement.
- (g) An experimental system has been installed. Automatic gates have been developed. Solenoid operated latches have been designed. A timer which will actuate the gates in sequence has been developed. The components have been hooked together with underground cable. The system has reduced the labor for irrigating the 15 acre field to closing 5 gates and pulling out the tabs on a time clock.
- (h) "Automation of Cut-back Furrow Irrigation," James E. Garton, R. P. Beasley and A. D. Barefoot, Agricultural Engineering, 45:6, pp. 328, 329, June 1964.
- (5476) SPATIALLY VARIED FLOW IN AN IRRIGATION DISTRIBUTION DITCH.
- (b) Oklahoma Agricultural Experiment Station.
- (c) Dr. James E. Garton, Oklahoma State Univ., Dept. of Agricultural Engrg., Stillwater, Okla. 74075.
- (d) Theoretical, applied research.
- (e) A digital computer study of spatially varied flow in level distribution bays of slip form lined concrete ditches. The purpose of the study is to develop design methods for distribution ditches which improve the uniformity of furrow irrigation.
- (g) A computer analysis of spatially varied flow in a common size of slip form ditch has been completed. Design nomographs which allow the selection of the depth of flow which results in the same water surface elevation at each end of the level bays have been developed. Hydraulic tests are planned.
- (h) "Spatially Varied Flow in an Irrigation Distribution Ditch" by James E. Garton and Albert L. Mink. Paper No. 64-732, presented to the 1964 Winter Meeting of the ASAE, New Orleans, Louisiana.
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- OREGON STATE UNIVERSITY, Hydraulics Laboratory.
- (3805) INVESTIGATION OF SUPERCRITICAL FLOW CHANNEL JUNCTIONS.
- (b) U. S. Dept. of Commerce, Bureau of Public Roads.
- (c) Prof. C. E. Behlke, Dept. of Civil Engrg., Oregon State University, Corvallis, Oregon.
- (d) Theoretical and experimental; applied research.
- (e) Wave effects resulting from the junction of two supercritical, open channel flows are being studied to determine the magnitude and the location of the wave pile up on the channel walls.
- (g) The prediction of wall pile-up.

(5300) HYDRAULIC INVESTIGATION OF BAFFLED, PIPE TYPE FISH LADDERS.

- (b) State of Oregon Fish Commission.
- (c) Prof. C. E. Behlke, Dept. of Civil Engrg., Oregon State Univ., Corvallis, Oregon.
- (d) Experimental; applied research.
- (e) High energy dissipation, enclosed fish ladders are being studied. Purpose is to develop relatively short, inexpensive fish ladders for small streams. Prototypes will be constructed and tested with adult salmon by the sponsoring agency.
- (g) Baffles have been developed which can be placed in pipes to yield large energy dissipation. In a 36-inch pipe, with a fish passage area of 15" by 15", the head loss is 0.55 ft. per foot of pipe, with a mean velocity of 4.5 ft/sec through the fish passage area.

THE PENNSYLVANIA STATE UNIVERSITY, Hydraulics Laboratory, Department of Civil Engineering.

Inquiries concerning the following projects, should be addressed to Prof. Sam Shulits, Head, Hydraulics Laboratory, 212 Sackett Building, The Pennsylvania State University, University Park, Penna. 16802.

(5181) ROUGHNESS COEFFICIENTS OF COBBLE-STREWN STREAMS.

- (b) Laboratory project.
- (d) Experimental; applied research; doctoral thesis.
- (e) Purpose: To provide a quantitative means of determining Manning's "n" or the coefficient K in $V = KR^{2/3} S^{1/2}$ in cobble-strewn streams, particularly for use in the slope-area method of computing flood discharge. In a tilting flume, 5.5 ft wide, 1 ft deep and 53 ft long, roughness patterns are created with large and small concrete blocks. Maximum discharge 5 cfs, corresponding to a small stream.
- (g) Previous work revealed systematic relationships among the roughness coefficient, Reynolds and Froude numbers, and a special quantitative parameter of the roughness pattern. See "Large-Scale Roughness in Open-Channel Flow" by J. B. Herbich and S. Shulits, Journal, ASCE Hydraulics Div., Vol. 90, No. HY6, Proc. Paper 4145, Nov. 1964. Whereas the latter dealt with cubical roughness elements in transverse rows and low flows, the current research treats two extensions:
(a) High flows in which the height of the roughness elements (concrete blocks) is a small fraction of the water depth and (b) the condition in cobble-strewn streams of cobbles on a rough rock bottom with slight protrusions.

(5182) TRANSITIONS IN SUPERCRITICAL FLOW.

- (b) Pennsylvania Department of Forests and Waters.
- (d) Experimental; applied research, design.
- (e) See Abstract in (g).
- (g) Transitions of three different shapes were tested for Froude numbers varying from 1.2 to 3.0, representing test flows of 0.56 to 5.27 cfs. Each transition connected an upstream trapezoidal channel with a downstream rectangular channel, all three parts lying on one straight center line and having constant and continuous invert slopes. One transition type had warped walls. The other two effected the transition with plane walls: one with a vertical surface above a sloping one, and the other with a sloping surface above a vertical one. The experiments with each of the three shapes covered combinations of five transition lengths with three depths in the trapezoidal approach channel. Twenty-eight different transitions were investigated. Tables and charts summarize the variation of the water

surface caused by the wave patterns due to supercritical flow, along the channel wall and the center line. Not only do these tables and charts give a picture of the complex wave patterns, but they are a basis for the design of transitions of the three tested shapes. A guide is offered for the application of the extensive data to actual design.

- (h) "Open-Channel Transitions in Supercritical Flow-Part A" by F. L. Blue, Jr., and S. Shulits, Hydraulics Laboratory Bulletin, December 1964.

Also a silent film, "Some Wave Phenomena in Transitions in Supercritical Flow."

(5183) EXNER EQUATIONS OF RIVER FORM.

- (b) Laboratory project.
- (d) Theoretical; basic research.
- (e) Felix Exner's simple erosion postulates of the 1920's result in equations which produce rather closely dune, bed and bank forms of real rivers. The accuracy of his equations and charts of river forms are being verified so that the concept embodied in the postulates can be extended and applied to the prediction of river development.
- (g) Two equations have been verified, one is in doubt.

THE PENNSYLVANIA STATE UNIVERSITY, Institute for Science and Engineering, Ordnance Research Laboratory, (Dr. John C. Johnson, Director), and Department of Aeronautical Engineering, (Dr. George F. Wislicenus, Department Head). Work done under Dr. George F. Wislicenus, Director of the Garfield Thomas Water Tunnel and Head, Department of Aeronautical Engineering.

(2832) MEASUREMENT OF FORCES ON A MODEL IN A WATER TUNNEL.

- (b) Laboratory project sponsored by the Bureau of Naval Weapons.
- (c) Mr. George B. Gurney, Ordnance Research Laboratory, University Park, Penna. 16802.
- (d) Experimental; developmental.
- (e) The problem concerns the measurement of forces on models in a water tunnel over a velocity range up to 80 feet per second, pressure ranges of 3 to 60 pounds per square inch absolute.
- (g) Two four component (lift, axial force, pitching and rolling moment) balances for use in water tunnels utilizing strain gaged pre-tensioned flexure beams as the force sensing devices have been in successful operation for four years. A Planar Motion Mechanism capable of imparting pitching and heaving motions to models is now under construction and should be in operation in March of 1963. The balance associated with this mechanism will measure all the hydrodynamic stability coefficients required in the equations of motion for a submerged body with four (4) degrees of freedom. These equations include the static, damping and acceleration derivatives. A balance which will measure unsteady forces on propulsors has been developed and successfully tested.

(3143) REDUCTION OF SKIN FRICTION DRAG.

- (b) Joint program of investigation with the General Electric Company, the United States Rubber Company and the Northrop Corporation sponsored by the Bureau of Naval Weapons.
- (c) Dr. John Lumley, Dr. Thomas E. Peirce and Mr. John McMahon, Ordnance Research Laboratory, University Park, Pennsylvania 16802.
- (d) Experimental, basic research; theoretical and applied research.
- (e) Investigations into the application of boundary layer control through suction and compliant surfaces for underwater bodies.
- (g) Several axisymmetric models employing

- discrete slots have been experimentally investigated, both in the field and in the laboratory. Experimental measurements of boundary layer transition and thickness aft of the transition have been made for a number of flat plates, which were covered with a compliant surface.
- (3486) TURBULENCE MEASUREMENTS IN WATER.
- (b) Laboratory project sponsored by the Bureau of Naval Weapons.
 - (c) Dr. John Lumley, Ordnance Research Lab., University Park, Pennsylvania. 16802.
 - (d) Experimental.
 - (e) Using a constant temperature probe, some turbulent flows at high Reynolds numbers will be investigated with particular attention to homogeneous grid-produced turbulence and turbulent dispersion in a shear flow.
 - (g) Measurements have been taken in a small water tunnel settling section determining the effect of various screens and honeycombs on turbulence.
 - (h) "The Constant Temperature Hot-Thermistor Anemometer," by J. L. Lumley, Proceedings of ASME Symposium on Measurement in Unsteady Flow, May 21-23, 1962, pp. 75-82.
- (3807) INVESTIGATION OF THE CAVITATION CHARACTERISTICS OF A FEW SIMPLE LIQUIDS.
- (b) Laboratory project sponsored by NASA.
 - (c) Dr. J. William Holl, Ordnance Research Lab., University Park, Pennsylvania. 16802
 - (d) Experimental, analytical; basic research.
 - (e) To investigate experimentally the cavitation characteristics of a few simple (as regards to vapor pressure and handling) liquids under conditions occurring in space and aircraft pumping machinery, and analyze the results so that a reliable basis for theory applicable to these conditions can be formulated.
- A small high speed water tunnel having test section velocities of 370 feet per second, pressures to 1000 pounds per square inch, temperatures to 300 degrees Fahrenheit, has been constructed and has been in operation since April of 1962.
- (g) Investigations of desinent cavitation at very high velocities on 1/4 inch diameter ogive noses indicates that the desinent cavitation number approaches the minimum pressure coefficient. Studies of cavitation hysteresis on ogive noses show that the cavitation delay time is a random function and is of significant duration e.g. 3 to 4 minutes.
 - (h) "Cavitation Hysteresis," by Allen L. Treaster, M.S. Dissertation, Department of Aeronautical Engineering, The Pennsylvania State Univ., June 1964.
- (4180) UNSTEADY FLOW INVESTIGATIONS AROUND AN ELLIPSOID OF REVOLUTION.
- (b) Laboratory project sponsored by Bureau of Naval Weapons.
 - (c) Dr. Maurice Sevik, Ordnance Research Lab., University Park, Pennsylvania 16802.
 - (d) Experimental and theoretical.
 - (e) A study of unsteady forces acting on an ellipsoid of revolution over a range of Reynolds numbers and body attack angles.
 - (f) Completed.
 - (g) A theoretical and experimental investigation of the lift and moment on an 8/1 ellipsoid of revolution performing small oscillations in a direction normal to the free stream has been carried out. The maximum circulatory lift coefficient is about half that obtained in steady flow. A phase lag of 20 degrees in build-up of lift was observed. The maximum pitching moment is reduced by 16 percent from that predicted by potential theory.
 - (h) "The Lift on an Oscillating Body of Revolution," by Mr. M. S. Sevik, Ph.D. Thesis, Department of Engineering Mechanics, The Pennsylvania State University, May 1963.
- (4181) DETERMINATION OF EFFECT OF TUNNEL BOUNDARIES ON THE FORCES ACTING ON A MODEL.
- (b) Laboratory project sponsored by Bureau of Naval Weapons.
 - (c) Dr. Thomas Peirce, Ordnance Research Lab., University Park, Pennsylvania 16802.
 - (d) Theoretical and experimental.
 - (e) Investigation of the errors introduced by the physical boundaries of tunnel walls on the measured forces on large models. The investigation covers both the axially symmetric case and when the models are at low angles of attack. Establishing the means for correcting these errors is also a part of this investigation.
 - (g) A method has been developed for the prediction of errors in drag caused by water-tunnel wall deviations. It is shown that small deviations in contour can cause a significant error in model drag measurements. Tunnel wall interference effects on model pitching moment have been investigated and a correction procedure established for models of low attack angle and diameters up to 1/3 tunnel diameter.
 - (h) "Tunnel Wall Interference Effects on the Drag and Pitching Moment of an Axisymmetric Body," by Mr. Thomas E. Peirce, Ph.D. Thesis, Dept. of Engineering Mechanics, December 1963.
- (4677) THE INVESTIGATION OF TWO-DIMENSIONAL UNSTEADY CAVITY FLOWS ABOUT FIXED SYMMETRIC BLUFF BODIES.
- (b) Laboratory project sponsored by Bureau of Naval Weapons.
 - (c) Dr. J. William Holl, Ordnance Research Laboratory, University Park, Penna. 16802.
 - (d) Experimental and theoretical.
 - (e) An investigation of the wake region behind supercavitating, two-dimensional wedges at zero degrees angle of attack is in progress with the purpose of determining the wake characteristics, in particular the Strouhal number as a function of Reynolds number, cavitation number and wedge apex angle.
- (4678) HYDRAULIC SERVOMECHANISM FOR AN UNDERWATER MISSILE.
- (b) Laboratory project sponsored by the Bureau of Naval Weapons and conducted under Mr. C. L. Key, Asst. Director, Ordnance Research Laboratory.
 - (c) Messrs. H. M. Jensen and R. E. Kershaw, Ordnance Research Laboratory, University Park, Pennsylvania 16802.
 - (d) Experimental, applied development and design.
 - (e) A high-performance hydraulic servomechanism for control of rudders and elevators in an underwater missile system. Specific design problems were instability caused by a resonant linkage and high-frequency oscillation of the servovalve.
 - (g) Stability was achieved by increasing the resonant frequency of the linkage, providing hydraulic damping with a bypass orifice, and lag-lead phase compensation in the servo amplifier. The high-frequency oscillation was eliminated by increasing the diameter of activator ports.
- (5106) INVESTIGATION OF TENSIONS IN LIQUIDS.
- (b) Laboratory project sponsored by NASA.
 - (c) Dr. J. William Holl, Ordnance Research Laboratory, University Park, Penna. 16802.
 - (d) Experimental and theoretical.
 - (e) Investigation of liquid tensions for a variety of liquids under a range of conditions employing a non-flow apparatus. Results will be compared to those obtained in a flowing system.
- (5107) INVESTIGATION OF THE KUTTA CONDITION IN UNSTEADY FLOW.
- (b) Laboratory project sponsored by Bureau of

- (c) Naval Weapons.
Dr. Maurice Sevik, Ordnance Research Laboratory, University Park, Penna. 16802.
 - (d) Experimental, theoretical; basic research.
 - (e) The validity of the Kutta-Joukowski criterion is being investigated for the prediction of control surface hinge moments in steady flow, or instantaneous forces on rapidly oscillating air and hydrofoils.
- (5108) JET INSTABILITY IN MERCURY.
- (b) Laboratory project sponsored by National Science Foundation.
 - (c) Dr. David P. Hoult, Ordnance Research Laboratory, University Park, Penna. 16802.
 - (d) Experimental and theoretical; basic research.
 - (e) The study involves the stability of a jet of mercury into mercury in the presence of a magnetic field. The magnetic field acts to stabilize the jet and thus control the rate of amplification of unstable oscillation. The experimental findings are then to be compared with appropriate small disturbance theory in an effort to further understand the instability of jets.
 - (h) "The Laminar Round Jet in an Axial Magnetic Field," by Dr. David P. Hoult. Paper given at the American Physical Society Meeting, Pasadena, California. November 22-24, 1964. Also submitted to the Physics of Fluids. "The Effect of an Axial Magnetic Field on the Stability of an Axial-Symmetric Jet or Wake," by Dr. David P. Hoult; submitted to the Physics of Fluids.
- (5590) INVESTIGATION OF SHED WING VORTICES AND THEIR DECAY.
- (b) Laboratory project sponsored by the Army Research Office, Durham, North Carolina.
 - (c) Dr. Barnes W. McCormick, Jr., Ordnance Research Laboratory, University Park, Penna. 16802.
 - (d) Experimental; analytical; basic research.
 - (e) The vortex sheet shed by a wind tunnel mounted, semi-span lifting wing has been investigated at various angles of attack and free-stream velocities. The vortex core has been studied by mapping the downstream flow field at distances up to 20 chord lengths. Tangential velocities of vortices have been determined by integrating the vorticity through the vortex core. The local vorticity is measured by a pitchless, cruciform vane which rotates in rotational flow. Rotational speeds of 40,000 rpm have been measured. Similar investigations will be conducted by mounting the vortex probe behind the wing of a full-scale flight test airplane. Qualitative characters of shed vortices have been studied by flying an airplane adjacent to a large tuft grid and photographing the motion of the tufts as the vortex moves across the grid.
 - (g) It is believed that after completion of the investigations it will be possible to predict the vortex geometry of an arbitrary aircraft as a function of the airplane configuration and distances downstream.
- (5591) BOILING BOUNDARY LAYER.
- (b) Laboratory project sponsored by the Bureau of Naval Weapons.
 - (c) Dr. David P. Hoult, Department of Aeronautical Engineering, The Pennsylvania State Univ., University Park, Pa. 16802.
 - (d) Theoretical.
 - (e) Theoretical investigation of the boiling boundary layer on a flat plate.
- (5592) EXPERIMENTAL INVESTIGATION OF SECONDARY FLOW IN AXIAL FLOW INDUCERS.
- (b) Laboratory project sponsored by NASA.
 - (c) Dr. George F. Wislicenus and Dr. B. Lakshminarayana, Dept. of Aeronautical Engineering, The Pennsylvania State Univ., University Park, Pa. 16802.
- (d) Experimental and theoretical.
 - (e) A three-foot diameter model of an axial flow inducer for a pump was built and will be tested with air, using smoke for direct observation of secondary motions in long and narrow vane passages. In addition, approximate measurements of the velocity distribution at inlet and discharge will be made to obtain at least a qualitative picture of the fluid motions under the predominant influence of viscous fluid friction.
- (5593) INVESTIGATION OF LAMINAR BOUNDARY LAYER AND TRANSITION IN THE VICINITY AND BETWEEN SUCTION SLOTS.
- (b) Laboratory project sponsored by the Bureau of Naval Weapons and the Office of Naval Research.
 - (c) Dr. Thomas E. Peirce and Mr. Charles F. Holt, Ordnance Research Laboratory, University Park, Pa. 16802.
 - (d) Experimental and theoretical.
 - (e) This project will examine the characteristics of the flow at the entrance to suction slots and determine the effect the suction slots have on the laminar boundary layer flowing into each slot. This investigation will be limited to plane radial slots and the effect that variations in slot shape have on the laminar boundary layer.
- (5594) GRID TURBULENCE IN DILUTE POLYMER SOLUTIONS.
- (b) Bureau of Naval Weapons and the Office of Naval Research.
 - (c) Dr. John L. Lumley and Mr. Andrew G. Fabula, Dept. of Aeronautical Engineering, The Pennsylvania State Univ., University Park, Pa. 16802.
 - (d) Experimental and basic research for Ph.D. thesis.
 - (e) Turbulent velocity measurements will be made behind a grid in a 48-foot towing tank filled with dilute polymer solution. Experimental spectra and correlation functions will be compared with previous measurements in Newtonian fluids and with theory, in order to investigate possible explanations of the Toms effect (the friction reduction in turbulent flow produced by extremely low concentrations of very high molecular weight polymers).
- (5595) TURBULENCE MEASUREMENTS IN THE VISCOUS SUBLAYER.
- (b) Bureau of Naval Weapons and the Office of Naval Research.
 - (c) Dr. John L. Lumley and Mr. Henry Bakewell, Ordnance Research Laboratory, The Pennsylvania State University, P. O. Box 30, State College, Pa. 16801.
 - (d) Experimental, basic research for Ph.D. thesis.
 - (e) u-u space-time correlations will be taken in the viscous sublayer under a turbulent boundary layer in glycerin. The sublayer thickness is such that a $y^+ = 5$ corresponds to 0.25 inches. It is hoped that these measurements will shed light on the dynamics of the sublayer, in particular on the translation velocities of disturbances there.
- (5596) THEORETICAL INVESTIGATION OF TURBULENCE FLOW OF NON-NEWTONIAN MEDIA.
- (b) Office of Naval Research.
 - (c) Dr. John L. Lumley and Mr. Kirtan Singh, Dept. of Aeronautical Engineering, The Pennsylvania State University, University Park, Pa. 16802.
 - (d) Theoretical, basic research for Ph.D. thesis.
 - (e) Machine calculations will be made of the initial effect on the energy budget resulting from a sudden change in the constitutive relation (from Newtonian to any of several non-Newtonian types) of a

fluid in isotropic, homogeneous turbulent motion. It is hoped that the investigation will provide insight into the mechanism by which low concentrations of high molecular weight additives markedly change the skin friction in turbulent shear flows (the Toms effect).

PRINCETON UNIVERSITY, School of Engineering and Applied Science.

(5184) FALL OF A SPHERE IN A HORIZONTALLY OSCILLATING FLUID.

- (b) Laboratory project.
- (c) Prof. Lucien M. Brush, Jr., Departments of Civil and Geological Engineering, Princeton University, Princeton, N. J.
- (d) Analytical and experimental, basic research, master's thesis.
- (e) The purpose of this research is to predict the temporal mean fall velocity of a spherical particle falling in a horizontally oscillating fluid. An analytical solution was derived for particles with a small (0.1) Reynolds number. A numerical solution is possible for large Reynolds numbers. Experimental verification of the appropriate equations is the purpose of the study. The results will be applicable to problems involving turbulent diffusion of sediment.

(5185) DYNAMIC STORAGE OF GROUNDWATER.

- (b) Laboratory project.
- (c) Dr. R. J. DeWiest, Assoc. Prof. of Geological Engineering, Princeton University, Princeton, New Jersey.
- (d) Analytical and experimental, basic research, master's thesis.
- (e) Purpose of the research is to investigate the dynamic behavior of a groundwater basin intersected by streams and from which water is withdrawn at a time dependent rate. An electric analog model (R-C) will be constructed.
- (h) Preliminary steady state study was published in the Journal of the Hydraulics Division, American Society of Civil Engineers, Nov. 1963. "Replenishment of Aquifers Intersected by Streams," pp. 165-191, available from the American Society of Civil Engineers.

(5186) MEASUREMENT OF UNSTEADY PRESSURES.

- (b) Laboratory project.
- (c) Prof. C. P. Kittredge, Dept. of Aerospace and Mechanical Sciences, Princeton University, Princeton, N. J.
- (d) Theoretical and experimental, M.S. thesis.
- (e) The differential equations of motion for a simple manometer system with non-linear damping have been programmed for an IBM 7094 data processing system. An experimental program to check the computation is planned.

(5480) INERTIAL EFFECTS IN TURBULENT SUSPENSIONS.

- (b) National Institute of Health, Public Health Service.
- (c) Prof. Lucien M. Brush, Jr., Departments of Civil and Geological Engineering, Princeton, N. J.
- (d) Theoretical and experimental; basic research.
- (e) The purpose of this research is to examine the inertial lag between particle motion and fluid motion in a turbulent suspension. A turbulence tank consisting of an oscillating three-dimensional grid will be used for the experiment. Measurements are to be made of the energy contribution to the system as a result of collisions between particles and the grid. By varying the frequency of oscillation, grid spacing and size, and particle density, an attempt will be made to describe the de-

tailed particle motion and the sediment diffusion coefficient.

PURDUE UNIVERSITY, Department of Agricultural Engineering.

(2596) THE USE OF A RAINFALL SIMULATOR FOR SOIL AND WATER CONSERVATION MANAGEMENT STUDIES.

- (b) Soil and Water Conservation Research Div., Agricultural Research Service, USDA and Purdue University. (See Agricultural Research Service, Corn Belt Branch, Project No. 4276).
- (c) Dr. L. Donald Meyer, ARS-SWC, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
- (d) Field investigation; applied research.
- (e) The rainfall simulator is used on runoff plots for comparison of treatments which effect erosion and infiltration. Research includes studies of tillage methods, crop residue management, slope, soil type, crop rotations, and intensity histograms. "Crop Residues and Surface Mulches for Controlling Erosion on Sloping Land Under Intensive Cropping", by L. D. Meyer and J. V. Mannering, Trans. ASAE 6, 1963. "Erosion-Control Effectiveness of Rotation Meadows", by J. V. Mannering, L. C. Johnson, L. D. Meyer, and B. A. Jones, Jour. Soil and Water Cons. 19: 91-95, June 1964. "The Effect of Minimum Tillage for Corn on Infiltration and Erosion", by J. V. Mannering, L. D. Meyer, and C. B. Johnson, Agronomy Abstracts, Am. Soc. of Agron., 1964.

(2837) TREATMENT OF SURFACE WATERS FOR DOMESTIC USE ON THE FARM.

- (b) Laboratory project.
- (c) Dr. E. J. Monke, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
- (d) Field investigation; applied and basic research.
- (e) The treatment of pond water by use of slow sand and diatomaceous earth filters is being evaluated. Improved designs are under investigation. The effects of algae growth and coagulation-sedimentation methods on filtration processes are being studied. Equipment for a study of electrophoretic control of slow sand filtration is currently under construction.
- (g) Diatomaceous earth filtration provides a safe and effective treatment process for pond water. With equipment available, excessive supervision of the filtration operation is needed. A small, automated diatomite filter system designed for single family operation is being evaluated.
- (h) "An Experimental Diatomite Filter Water Treatment System for Family Use", by E. J. Monke, K. J. Albrecht, H. R. Wilke, and G. G. Fassnacht, Research Progress Report 56, Agr. Exp. Sta., Purdue Univ., 1963. "Water Use Goes Up at the Southern Indiana Forage Farm", by E. J. Monke and K. J. Albrecht, Research Progress Report 117, Agr. Exp. Sta., Purdue Univ., 1964.

(3490) INVESTIGATION OF FLOW CHARACTERISTICS IN DRAIN TILE AND THE RELATIONSHIP OF THESE FLOW CHARACTERISTICS TO SEDIMENTATION.

- (b) Laboratory project.
- (c) Mr. L. F. Huggins, Agricultural Engineering Department, Purdue Univ., Lafayette, Indiana 47907.
- (d) Experimental; basic research.
- (e) A 60 - foot model drain capable of recirculating sediment-laden flow has been constructed. Drain slopes at which incipient deposition occurs are being

- investigated.
- (g) Five different flow regimes were observed to occur during the transition from part full to full flow in a circular drain. Implications with regard to tile drain breathers for the relief of below atmospheric pressures were shown.
- (h) "Point of Impending Sediment Deposition for Open Channel Flow in a Circular Conduit", by C. T. Haan, M.S. Thesis, Purdue Univ., 1964.
- (3808) DEVELOPMENT AND REFINEMENT OF METHODS FOR ESTIMATING FIELD RUNOFF AND SOIL LOSS.
- (b) Soil and Water Conservation Research Div., USDA, and Purdue University. (See Agri. Research Service, Corn Belt Branch, Project No. 4274).
- (c) Mr. Walter H. Wischmeier, ARS-SWC, Agric. Engineering Dept., Purdue Univ., Lafayette, Indiana 47907.
- (d) Experimental; development.
- (e) The relationships of numerous rainstorm characteristics, topographic features, soil characteristics and surface conditions to field runoff and soil erosion are being evaluated from plot data obtained under natural and/or simulated rainfall. Basic plot and small watershed data on an individual storm basis have been assembled in an ARS central runoff and soil-loss data lab. at Purdue Univ., from 24 states. The data represent results of cooperative research studies over the past 32 years at 47 locations.
- (g) In studies at 47 locations, average annual runoff from cropped plots ranged from 3 to 36 percent of rainfall. Amount of runoff was influenced by soil properties, slopes, cropping systems, productivity levels, residue management, tillage methods, and intercrops. On silt loams and silty clay loams, it decreased significantly with increases in percent organic matter. For other soils, percentages of sand and clay were influential. Runoff per unit area increased with percent slope; with corn the relationship was curvilinear at all crop stages, with small grain or meadow cover it was linear.
- (h) "Relation of Field-Plot Runoff to Management and Physical Factors", by W. H. Wischmeier. Agronomy Abstracts, Am. Soc. of Agron., 1964.
- (4182) THE MECHANICS OF EROSION BY RAINFALL AND RUNOFF.
- (b) Soil and Water Conservation Research Div., Agricultural Research Service, USDA and Purdue University, (See Agricultural Research Service, Corn Belt Branch, Project No. 4275.)
- (c) Dr. L. Donald Meyer, ARS-SWC, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
- (d) Experimental; basic research.
- (e) The influence of slope inclination, slope length, particle size, particle shape, and wind velocity on the resulting splash and runoff erosion are being investigated in the laboratory. Methods for simulating rainfall, slope length, soil and wind have been developed. This study is providing an understanding of the mechanics of the process involved in erosion and the basic relationships of the above variables.
- (h) "Mechanics of Soil Erosion by Rainfall and Runoff as Influenced by Slope Length, Slope Steepness, and Particle Size", by L. D. Meyer, Ph.D. thesis, Purdue Univ., 1964. "The Effect of Particle Size and Shape on Runoff Erosion", by G. D. Bubenzer, M.D. thesis, Purdue Univ., 1964. "Splash Erosion as Affected by the Angle of Incidence of Raindrop Impact", by W. M. van Heerden, Ph.D. thesis, Purdue Univ., 1964. "Mechanics of Soil Erosion by Rainfall and Overland Flow as Influenced by Slope, Runoff Rate, and Particle Size", by L. D. Meyer and E. J. Monke, ASAE Paper No. 64-215, 1964.
- (4183) SUBSURFACE DRAINAGE OF BLOUNT SILT LOAM.
- (b) Laboratory project.
- (c) Dr. E. J. Monke, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
- (d) Field investigation; applied research.
- (e) Various spacings between parallel subsurface drains are under investigation to determine their effectiveness in water removal and crop response. Continuous records of tile discharge are being made and crop yields are determined at harvest time.
- (4681) EVALUATION OF PLASTIC-LINED MOLE DRAINS AND INSTALLATION EQUIPMENT IN MUCK SOILS.
- (b) Soil and Water Conservation Research Div., USDA, and Purdue University. (See Agri. Research Service, Corn Belt Branch, Project No. 4271).
- (c) Dr. E. J. Monke, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
- (d) Field investigation; applied research.
- (e) The primary purpose of this investigation is to determine the stability with time of various cross-sectional types of plastic-lined mole drains in muck soil. Secondary objectives are concerned with the improvement of the installation equipment.
- (f) Completed.
- (g) Failures were noted with all of the cross-sectional types of plastic-lined mole drains. The drain with interlocking edges stood up best. The causes of failure were due to a shallow installation depth, vertical misalignment, and the fluidity of the soil in the upper profile.
- (h) "Plastic-Lined Mole Drains", by J. L. Fouss, Agricultural Handbook Series Publication.
- (5481) EVALUATION OF THE PARALLEL DITCH SYSTEM FOR SURFACE DRAINAGE ON CLERMONT SOIL.
- (b) Laboratory project.
- (c) Mr. D. R. Sisson, Agricultural Engineering Dept., Purdue Univ., Lafayette, Indiana 47907.
- (d) Field investigation; applied research.
- (e) A parallel ditch system of surface drainage is being compared to the conventional drainage practices on Clermont silt loam.
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- PURDUE UNIVERSITY, Department of Agronomy.
- (4679) FLOW LAWS FOR THE MOVEMENT OF WATER IN SOIL.
- (b) Laboratory project.
- (c) Dr. Dale Swartzendruber, Department of Agronomy, Purdue Univ., Lafayette, Indiana.
- (d) Experimental and theoretical; basic for Ph.D. thesis.
- (e) The validity of basic equations for water relationships in soil, such as Darcy's proportionality and Buckingham's capillary potential function, is being tested under various circumstances. Revised equations and mathematical solutions for deviating behavior are also being sought.
- (g) An attempt was made to use the pressure-plate outflow method for measuring water diffusivity, specific water capacity, and capillary conductivity as a function of water content. Measurements were made on two nonswelling porous materials over a pressure range of 100 to 900 mb., but with pressure steps ranging from 25 to 400 mb. The experimental outflow curves did not conform to theoretical predictions, thus making it difficult to compute a meaningful diffusivity value. Also, for sufficiently small pressure steps, the specific water capacity was a fluctuating function of water content, rather than changing monotonically. Since the capillary

conductivity is the product of the water diffusivity and the specific water capacity, a meaningful conductivity value is made quite difficult to determine. It is concluded that present mathematical solutions for the pressure-plate outflow method are inadequate. In a second study, involving water movement into initially air-dry, horizontal columns of soil, moisture distributions at various times were found not to reduce to a single curve when adjusted by the square-root-of-time factor as required mathematically by the solution of the nonlinear diffusion equation. The discrepancies found in this second study may be due to the same factors as are causing the deviations in the pressure-plate outflow method.

PURDUE UNIVERSITY, School of Civil Engineering.

(2639) HYDRAULICS OF RIVER FLOW UNDER ARCH BRIDGES.

- (b) State Highway Department of Indiana and Bureau of Public Roads.
- (c) Dr. J. W. Delleur, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Indiana 47907.
- (d) Experimental; for master theses.
- (e) The purpose of the research is to study systematically the hydraulic efficiency of waterways under arch bridges, to provide a criterion for determining the proper clear span of arch bridges so as to compensate for the loss of efficiency at high flows, to provide a method for computing the backwater upstream of arch bridges and to provide a method of indirect flood discharge measurement from high water marks observations.
- (f) Completed.
- (g) A method for the determination of backwater and energy loss has been obtained for arch bridge constrictions. The effects of various constriction geometries have been considered. The following factors were investigated: The effect of the amount of contraction, of the length of the contraction, of wingwalls, of skew and of eccentricity. Dual bridges, two span bridges, and arch segment bridges were also investigated. The effect of bridge submergence was studied.
- (h) Discussion on "Roughness Spacing in Rigid Open Channels" by P. F. Biery and J. W. Delleur, Transactions ASCE Vol. 128 (1963) p. 372.
- "Hydraulics of Single Span Arch Bridge Constrictions" by P. F. Biery and J. W. Delleur, Journal Hydraulics Division, ASCE, Vol. 82, HY5, March 1962.
- "Hydraulics of River Flow Under Arch Bridges," Joint Highway Research Project, Purdue Univ., Rept. No. 11, June 1964, (2 Volumes).

(2840) MECHANISM OF TURBULENCE IN FREE SURFACE FLOW.

- (b) Purdue Research Foundation and National Science Foundation.
- (c) Dr. J. W. Delleur and Dr. G. H. Toebes, Hydromechanics Laboratory, Civil Engineering, Purdue University, Lafayette, Ind. 47907.
- (d) Theoretical and experimental for Ph.D. thesis.
- (e) Experimental and theoretical studies of:
 - (a) Boundary layer development in free surface flow with applications to channel conveyance, air-entrainment and flow measuring structures;
 - (b) Secondary flow development in free surface flow with applications to channel conveyance, pollutant dispersion and sedimentation problems. Studies based on mean velocity and turbulent velocity component data.
- (g) Improvements and evaluation of hot-wire anemometer equipment for liquids. Original turbulence data and their analysis for the flow establishment reach in an open channel of moderate aspect ratio.
- (h) "Mechanism of Turbulence in Free Surface Flow", by J. W. Delleur, and G. H. Toebes, Hydromechanics Laboratory, Purdue Univ., Technical

Report No. 9 (Final Report NSF-G) August '64. "Les echanges thermiques de l'anemometre a fil chaud place obliquement dans un ecoulement," by J. Delleur, Comptes Rendus, Acad. Sc. Paris, Vol. 259, p. 712, July 27, 1964. "L'emploi de l'anemometre a fil chaud comme clinometre de precision," J. Delleur, Comptes Rendus, Acad. Sc. Paris, Vol. 259, p. 985, August 3, 1964.

(2841) HYDROLOGY OF SMALL WATERSHEDS IN INDIANA.

- (b) State Highway Department of Indiana and Indiana State Flood Control and Water Resources Commission.
- (c) Dr. J. W. Delleur, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
- (d) Analysis and field investigation for Ph.D. thesis.
- (e) The purpose of the research is to study the hydrology of watersheds less than 200 square miles throughout the State of Indiana to improve the existing methods for estimating the runoff from these watersheds.
- (g) Peak discharges were analyzed statistically and a correlation was obtained between the 25 year peak discharge and geomorphological characteristics of the watersheds. Peak discharges for other frequencies may also be obtained. A synthetic design hydrograph was developed on the basis of the instantaneous hydrograph theory. The hydrograph is determined by two parameters which have been related statistically to geomorphological characteristics of the watershed. The theory of overland flow has been investigated from a hydrodynamics standpoint.
- (h) "Determination of Peak Discharge and Design Hydrographs for Small Watersheds in Indiana," by I. P. Wu, J. W. Delleur, M. H. Diskin, published by Indiana Flood Control and Water Resources Commission, Indiana State Highway Commission, and Purdue University (Oct. 1964); available from Joint Highway Research Project, Purdue University.

(4191) MEANDER FLOOD PLAIN MODEL.

- (b) Engineering Experiment Station; Purdue Research Foundation; Agricultural Research Service.
- (c) Dr. G. H. Toebes, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ. Lafayette, Ind. 47907.
- (d) Analytical and experimental research for Ph.D. thesis.
- (e) A 5- x 30-foot styrofoam meander-flood plain model has been built with adjustable slope, side walls and channel dimensions. Flow visualization equipment and a directional Prandtl tube have been used to study the internal flow field characteristics.
- (g) First stage of investigation is completed. Several experimental stage-discharge relations are available. Internal characteristics of flow field have been determined for a number of cases. Implications of findings to basic facets of the meander problem, to flood routing and to river improvements studies have been considered.

(5110) HOT-WIRE PHYSICS IN LIQUIDS.

- (b) Purdue Research Foundation.
- (c) Dr. J. W. Delleur, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
- (d) Theoretical and experimental for Ph.D. thesis.
- (e) The purpose of this research is to investigate the heat transfer characteristics of hot wires in liquids, to determine their sensitivity to fluctuations of velocity, temperature and flow direction, and to arrive at an understanding of the physical causes of their limitations.
- (g) System response equations have been formulated and determination of necessary empirical constants is in progress. Equipment is

operative and data are being collected.

(5111) HYDROELASTIC STRUCTURING OF SEPARATED FLOW AND WAKE TURBULENCE.

- (b) Purdue Research Foundation.
- (c) Dr. G. H. Toebes, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
- (d) Analytical and experimental.
- (e) Analytic and experimental study aimed at correlating the hydroelastic loading of structural components and the turbulent structure of the generated wake and separating boundary layers.
- (g) Force, displacement and wake turbulence measurements are being made for variety of cylindrical components and plate-like structures. Reduction of data by means of spectrum analysis equipment.
- (h) "Flow Induced Excitation of Structural Vibrations," by G. H. Toebes, presented at ASCE Annual Convention, New York (October 1964).

(5112) TURBULENCE MEASUREMENTS IN LIQUIDS.

- (b) David Taylor Model Basin, Dept. of the Navy.
- (c) Dr. G. H. Toebes, Hydromechanics Lab., School of Civil Engrg., Purdue Univ., Lafayette, Ind. 47907.
- (d) Theoretical and experimental; for Ph.D. theses.
- (e) Analytic and experimental investigations aimed at optimization of turbulence measurements in liquids using hot-wire anemometer equipment and to compare performance characteristics of hot-wire equipment with hot-film thermistor, electro-magnetic and pressure transducers.
- (g) Collecting of liquid anemometry data is in progress. Special calibration and test equipment has been built. Spectrum analysis equipment has been adapted for above studies. Special recirculation equipment for laboratory water supply is being installed.

(5482) URBAN HYDROLOGY FOR SELECTED SITES IN INDIANA.

- (b) Indiana Flood Control and Water Resources Commission.
- (c) Dr. J. W. Delleur, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
- (d) For M.S. Thesis.
- (e) Rainfall-runoff relationships are studied for three selected sites in Indiana in order to test scientific methods of estimating the surface runoff and to obtain design criteria that can be used by practicing engineers.
- (g) An urban watershed is being instrumented in West Lafayette, Indiana.

(5483) PERFORMANCE CHARACTERISTICS OF LARGE SCALE HYDROMECHANICS LABORATORY EQUIPMENT.

- (b) Purdue University, NSF (Fellowship).
- (c) Dr. G. H. Toebes, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
- (d) Design, theoretical, experimental; for Ph.D. thesis.
- (e) Under design are a 35' x 1.5' x 3' and a 90' x 6' x 3' tilting glass-lined flumes. The largest flume will accommodate sediment recirculation. A number of design problems is being studied which will be verified upon completion of the equipment. The main problems are: uniformity of inflow from headbox; residual turbulence in inflow; the boundary layer development in free surface flow and the length of flow establishment.
- (g) The smaller flume is completed and measurements are being started using pressure transducers and hot-wire equipment.

(5484) DESIGN OF INSTRUCTIONAL EQUIPMENT FOR LABORATORY DEMONSTRATIONS IN FLUID MECHANICS.

- (b) Engineering Experiment Station, National

- (c) Science Foundation, Purdue University.
- (c) Dr. J. W. Delleur and Dr. G. H. Toebes, Hydromechanics Laboratory School of Civil Engineering, Purdue University, Lafayette, Ind. 47907.
- (d) Developmental, M.S. Theses.
- (e) Evaluation of the various means of conducting an undergraduate laboratory course in Hydromechanics; evaluation of the subject matter to be investigated, and design of specific equipment.
- (g) The design of the following apparatuses have been completed: rotating cylinder apparatus, radial flow apparatus, small wind tunnel, unsteady flow apparatus, cavitation apparatus pressure measurement apparatus, viscous flow apparatus.
- (h) "The Function and Form of the Undergraduate Laboratory in Fluid Mechanics" by V. T. Ricca, M.S. Thesis, June 1964.

(5485) TURBULENT DIFFUSION OF CONTAMINANTS IN SHEAR FLOWS.

- (b) Laboratory project.
- (c) Dr. V. W. Goldschmidt, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Indiana 47907.
- (d) Theoretical and experimental for M.S. and Ph.D. Theses.
- (e) Insight into the turbulent and convective dispersion of contaminants in the atmosphere and oceans is sought. At present a wind tunnel is being designed to study the relationship of contaminant size to turbulent diffusivity and the effect of temperature gradients on the overall mass transfer coefficient.

(5486) TIME RATE OF DEVELOPMENT OF INFILTRATION OF SURFACE WATERS INTO INCLINED STRATA.

- (b) School of Civil Engineering, Purdue Univ.
- (c) Dr. M. E. Harr, School of Civil Engineering, Purdue Univ., Lafayette, Indiana 47907.
- (d) Experimental and theoretical for Ph.D. Thesis.
- (e) The study is aimed at the development of a rational method of determining the locus of the free surface for flow due to rainfall of varying intensity into inclined strata.
- (g) Methods of solution will be developed whereby one can predict with some degree of reliability at any time the location of the wetted front and the quantity of seepage.

PURDUE UNIVERSITY, School of Electrical Engineering.

(4499) AN INVESTIGATION OF PULSE WIDTH MODULATED HYDRAULIC CONTROL SYSTEMS.

- (b) Laboratory project.
- (c) Dr. J. E. Gibson, Dir., Control and Information Systems Lab., School of Elec. Engineering, Purdue Univ., Lafayette, Ind. 47907.
- (d) Experimental and analytical investigation; basic research for doctoral thesis.
- (e) An analytical model for a pulse width modulated hydraulic servo is developed. A theoretical investigation of the closed loop system is performed. The results of this analysis are checked with the simulated model and with the actual system.
- (g) The theoretical closed loop investigation has been completed. It is capable of predicting subharmonic oscillations and of predicting the equivalent d.c. transfer characteristic of the pulse width modulator.

PURDUE UNIVERSITY, Jet Propulsion Center.

(2374) MASS TRANSFER IN ANNULAR, TWO-PHASE FLOW IN A VERTICAL TUBE.

- (b) National Science Foundation.
- (c) Dr. M. J. Zucrow, Jet Propulsion Center, Purdue University, Lafayette, Indiana 47907.

- (d) Experimental and theoretical; basic research for Master's and Ph.D. degrees.
- (e) This problem is concerned with the analytical and experimental study of the mass transfer from an annular liquid film on the inside wall of a vertical circular tube to a co-current gas flow in the core of the tube. Systematic experiments have been conducted for determining the effect of the rates of flow of air and liquid, the length of the tube, and the temperature difference between air and liquid upon the rate of mass transfer from the liquid film. Characteristics of the liquid film and the gas-liquid interface will be investigated and correlated with the aforementioned mass transfer measurements.
- (h) "First Annual Status Report for Mass Transfer in Annular, Two-Phase Flow," G. R. Schneider, Interim Report No. I-63-10, Jet Propulsion Center, Purdue Univ., Lafayette, Indiana, December 20, 1963 (available from Purdue).

(5487) LIQUID FILM COOLING IN ROCKET MOTORS.

- (b) Office of Naval Research, Power Branch.
- (c) Dr. M. J. Zucrow, Jet Propulsion Center, Purdue Univ., Lafayette, Indiana 47907.
- (d) Experimental and theoretical; basic research for Master's and Ph.D. degrees.
- (e) This program is part of a continuing analytical and experimental study of liquid film cooling in rocket motors. The current phase is concerned with the fundamental mechanisms of heat and mass transfer related to the liquid film in strictly controlled experiments in a wind tunnel. A liquid film is established on a polished flat plate. Air in both cold flow and at 1000R at a total pressure from 100 psia to 750 psi is passed over the liquid film. Negative pressure gradients of various values are induced by contoured sections. The temperature distribution in the test plate and the profiles of velocity, temperature and concentration will be determined for various different combinations of flow parameters. Film stability and film thickness will also be investigated.

PURDUE UNIVERSITY, Automatic Control Laboratory,
School of Mechanical Engineering.

(4197) FLUID LINE DYNAMICS.

- (b) Laboratory project.
- (c) Prof. Rufus Oldenburger, School of Mech. Engineering, Purdue Univ., Lafayette, Ind. 47907.
- (d) Theoretical and experimental project; Master's and Doctor's Thesis Research.
- (e) Mathematical models in use for systems with significant fluid lines are generally so complicated as to make design with such models impractical. In this investigation models are sought which are as simple as possible but which still adequately describe the response of the system to the class of disturbances of interest. Using infinite product expansions of transcendental functions satisfactory results have been obtained for single conduits terminating in lumped elements. Viscosity, boundary effects and line vibration are being considered in the analytical work. Frequency response runs to verify the theory are being made to determine the range for which solutions obtained are applicable. The theoretical and experimental approaches are being extended to systems with two or more lines. Rational approximations to the transfer functions of such systems are sought where the accuracy of the approximation can be seen directly from the approximation, as is the case where infinite products have been applied. Studies so far have been restricted to medium and large diameter lines. They are being extended to very small lines in the capillary class.

The rate of dispersion of a pressure wave in a single line of constant cross section is also under study and the reinforcement of such a wave traveling back and forth in a conduit closed at both ends.

- (g) Theory and tests show that for a wide range of operation encountered in practice flow through bends may be treated as flow through straight conduits. Mathematical models developed for straight fluid lines describe their response to high frequency. However, if resonance effects are to be included a certain complication of the model is necessary, beyond which further simplification is not possible.
 - (h) "Simplification of Hydraulic Line Dynamics by Use of Infinite Products," R. Oldenburger and R. E. Goodson. Trans. of the American Society of Mechanical Engineers, Journal of Basic Engineering, Vol. 86, Series D, No. 1, March 1964, pp. 1-10.
- "Experimental Dynamic Response of Fluid Lines," by William J. Roberts, M. S. Thesis, Purdue University, January 1963. Available from Automatic Control Center.

ROCKY MOUNTAIN HYDRAULIC LABORATORY.

(5488) RELIABILITY OF RELEASE OF BURIED FLOATS TO DETERMINE DEPTH OF SCOUR.

- (b) Laboratory project.
- (c) Prof. C. J. Posey, Director, Rocky Mountain Hydraulic Laboratory, Allenspark, Colorado 80510.
- (d) Experimental; master's thesis.
- (e) Scour model studies were conducted to determine the reliability of release of floats which were either buried or placed through casing jetted to desired depths.
- (f) Completed.
- (g) Except for the shallower-placed jetted floats breaking loose as soon as their tops were exposed, all floats remained in place until more than half uncovered, regardless of relative buoyancy, lack of soil cohesion, and vibration to which the nearby pier was subjected.

ST. ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA.

Inquiries concerning Projects 2144, 2603, 3153, 3502, 3824, 4199, 4200, 4201, 4209, 4691, 4693, 4696, 4697, 4699, 4700, 5187, 5188, and 5493 to 5507, inclusive, should be addressed to Director, St. Anthony Falls Hydraulic Laboratory, Mississippi River at Third Avenue S. E., Minneapolis, Minnesota, 55414.

Inquiries concerning Projects 111, 1168, 1929, and 2386, which are conducted in cooperation with the Agricultural Research Service, should be addressed to Mr. Fred W. Blaisdell, Hydraulic Engineer, Soil and Water Conservation Research Division, Agricultural Research Service, St. Anthony Falls Hydraulic Lab., Mississippi River at Third Avenue S. E., Minneapolis, Minnesota, 55414.

Inquiries concerning Project No. 194, which is conducted in cooperation with the Corps of Engineers and the U. S. Geological Survey, should be addressed to Engineer in Charge, Mr. Byron Colby, Federal Inter-Agency Sedimentation Project, St. Anthony Falls Hydraulic Laboratory, Mississippi River at Third Avenue, Minneapolis, Minnesota, 55414.

(111) CLOSED CONDUIT SPILLWAY.

- (b) Agricultural Research Service, U. S. Dept. of Agriculture, in cooperation with the Minnesota Agricultural Expt. Station and the St. Anthony Falls Hydraulic Laboratory.
- (d) Experimental; generalized applied research for development and design.
- (e) A two-sided drop inlet having a width equal

- to the pipe diameter and a variable length is currently being tested to determine the effect of orifices in a drop inlet on the spillway performance. The tests on the drop inlet without orifice and having a flat bottom have been completed; tests of a drop inlet having a semi-circular bottom are planned. The anti-vortex device consists of a horizontal plate supported above the crest of the drop inlet by end piers. The characteristics, performance, losses, and pressures in the drop inlet and on the anti-vortex plate are being determined for various combinations of drop inlet length, and height and overhang of the anti-vortex plate. Water is used as the model fluid to determine the performance characteristics, and head-discharge relationships during flows of water-air mixtures. For full flow, air is used as the model fluid to determine the various energy loss coefficients and the pressure coefficients.
- A square drop inlet having a hood barrel entrance is being tested to determine entrance loss coefficients for various drop inlet sizes and heights and various barrel slopes. Previous tests have evaluated the performance of this type of inlet.
- The effect of low-level orifices on the performance of the two-way drop inlet spillway has been studied.
- (g) The theory of closed conduit spillways has been developed, verified, and published. Results of tests on many forms of the closed conduit spillway entrance have been published. Pipe culverts laid on steep slopes may flow completely full even though the outlet discharges freely. Generalized methods for analysis and reporting of the results have been developed. The use of air as the model fluid has been verified by comparing test results with those obtained using water as the model fluid.
- The drop inlet with the horizontal anti-vortex device causes the spillway to act as a self-regulating siphon when the headpool level approximates the anti-vortex plate elevation. The height of the anti-vortex plate above the drop inlet crest and the overhang of the anti-vortex plate determine the effectiveness of the plate as an anti-vortex device. For one form of the inlet, tests have been made to determine the crest loss coefficient, the barrel entrance loss coefficient, the pressures on the plate and the drop inlet, the general performance of the inlet, minimum and maximum permissible plate heights, and the head-discharge relationship for plate control. Variables have been the length of the drop inlet, the barrel slope, the height and overhang of the anti-vortex plate, and the sidewall thickness.
- Tests on the hood drop inlet have shown that the hood barrel entrance can be used to reduce the minimum required height of the drop inlet. Minimum sizes of drop inlet and anti-vortex devices have been determined.
- Tests of low-stage orifices in the two-way drop inlet have shown that improper location and improper proportioning of the orifices can prevent priming of the spillway. The proper location and size of the orifices have been determined.
- (1168) A STUDY OF CANTILEVERED OUTLETS.
- (b) Agricultural Research Service, U. S. Dept. of Agriculture, in cooperation with the Minnesota Agricultural Expt. Station and the St. Anthony Falls Hydraulic Laboratory.
- (d) Experimental; generalized applied research for design.
- (e) Pipe outlet conduits for small spillways are frequently cantilevered beyond the toe of the earth dam. Attempts will be made to determine quantitatively for the size of the scour hole to be expected under various field conditions.
- (f) Preliminary planning and study.
- (1929) DRAIN TILE JUNCTION LOSSES.
- (b) Minnesota Agricultural Expt. Station in cooperation with the Agricultural Research Service, U. S. Dept. of Agriculture and the St. Anthony Falls Hydraulic Laboratory.
- (c) Prof. Philip W. Manson, Agricultural Engrg. Dept., University of Minnesota, St. Paul Campus, St. Paul, Minn. 55101.
- (d) Experimental; generalized applied research for design.
- (e) The junction losses in drain tile flowing full are determined for laterals of different sizes entering mains of different sizes at various angles. The laterals enter the main at the centerline. Additional tests have been made with the crowns (or inverts) of both main and lateral in the same plane.
- (f) Completed.
- (g) Tests have been completed on sharp edge junctions entering the main at angles varying in 15 degree increments from 15 degrees to 165 degrees. Both the lateral and the main are completely full. The tests cover all possible combinations of discharge in the lateral and in the main. Laterals having areas 1/1, 1/2, 1/4, 1/7, and 1/16 that of the main have been tested. A color motion picture film entitled "Energy Losses at Converging Pipe Junctions" has been completed and is available. The 16 mm film is 800 feet long.
- (2386) GENERALIZED DESIGN OF TRANSITIONS FOR SUPERCRITICAL VELOCITIES.
- (b) Agricultural Research Service, U. S. Dept. of Agriculture, in cooperation with the Minnesota Agricultural Experiment Station and the St. Anthony Falls Hydraulic Lab.
- (d) Experimental; generalized applied research for development and design.
- (e) Studies will be made to develop a transition and to determine the rules for its design. The transition will be used to change the flow cross section from circular to rectangular when the velocities are supercritical.
- (f) Suspended.
- (2144) EXPERIMENTAL AND ANALYTICAL STUDIES OF HYDROFOILS.
- (b) Office of Naval Research, Department of the Navy.
- (d) Experimental and analytical; basic research.
- (e) Investigation of the unsteady flow characteristics of ventilated hydrofoils of finite span in the vicinity of a free surface.
- (g) Unsteady flow characteristics were investigated for a ventilated foil experiencing either a sudden change in angle of attack, a sudden reduction in air-injection rate to the cavity, or a sinusoidal heaving motion. With forced-ventilated foils, considerable unsteadiness effects were observed for the first two types of unsteady motion. The experimental tests with the heaving foil are not yet completed.
- (h) "Further Studies of Ventilating Cavities on Submerged Bodies," by F. R. Schiebe and J. M. Wetzel, St. Anthony Falls Hydraulic Laboratory Project Report No. 72, (in preparation).
- (2603) WATER TUNNEL AIR CONTENT STUDIES.
- (b) David Taylor Model Basin, Dept. of the Navy.
- (d) Analytical and experimental applied research.
- (e) Establishment of procedures for acoustically measuring the size and number of small gas bubbles existing in water.
- (f) Completed.
- (g) Studies have validated the use of acoustic attenuation as a measure of the size and concentration of free air bubble nuclei in the range believed to exist in water tunnel cavitation tests.
- (h) "A Water Tunnel Air Content Meter," by John M. Killen and John F. Ripken, St. Anthony

(3153) FLOW ABOUT BODIES AT SMALL CAVITATION NUMBERS.

- (b) Office of Naval Research, Department of the Navy.
- (d) Experimental and analytical; basic research.
- (e) A flat plate and a cambered hydrofoil are tested in a free-jet tunnel under super-cavitating conditions. The unsteady flow due to the oscillation of a trailing flap as influenced by one or two free surfaces is being studied.
- (h) "Measurements of the Unsteady Force on Cavitating Hydrofoils in a Free Jet," by C. S. Song, St. Anthony Falls Hydraulic Laboratory Technical Paper No. 49, Series B, 56 pages, June 1964.

(3502) MANGLA SPILLWAY STUDIES.

- (b) Harza Engineering Company, Chicago; Binnie and Partners, London; Government of Pakistan.
- (d) Experimental; design and operation.
- (e) A 1:300 scale section model consisting of half the control structure and basin and a 1:150 scale comprehensive model for study of all important hydraulic features. A 1:216 scale section model consisting of two control structure gates for study of pressures and gate calibration. A 1:300 scale comprehensive approach model for study of flow conditions in approach. Two 1:150 scale section models, one a detailed study of pressures and forces on baffle blocks, one a detailed study of waves on the basin side walls. Typical dimensions of earth fill dam spillway include a drop in water level of 330 ft, and a design discharge of 900,000 cfs through a two-stage stilling basin energy dissipator.

(3824) SURFACE CHARACTERISTICS OF AIR ENTRAINED FLOW IN STEEP CHANNELS.

- (b) Laboratory project.
- (d) Analytical and experimental investigation of the air concentration, velocity distribution, and surface roughness of water flow in steep open channels, Ph.D. thesis.
- (e) Experimental investigation was carried out on the SAF high velocity channel for slopes up to 53 degrees. Velocities were measured by means of a pitot tube and high speed photography. Air concentration was measured by the SAF concentration meter. The surface elevation was measured by a device which measures the average time the surface is above a given elevation.
- (f) Experimental work completed.

(4109) GEOMETRY OF AIR CAVITIES IN A BOUNDARY LAYER.

- (b) David Taylor Model Basin, Dept. of the Navy.
- (d) Experimental; basic research.
- (e) Experiments performed to observe the geometry of the air cavity formed downstream of wedges mounted on channel wall when air is introduced through ports on downstream face of the wedge. Geometry of cavity and air demand will be observed in relation to wedge length and thickness for case of single wedge and for a series of wedges at various longitudinal spacings. The ultimate objective is to study drag reduction due to presence of air in boundary layer.
- (g) Cavity geometry and air demand obtained for single wedges from 2.5° to 90° semi-angle. Influence of blockage ratio and free surface on cavity formation has been studied.
- (h) "Cavity Formation and Associated Drag in a Supercavitating Flow Over Wedges in a Boundary Layer," by H. G. Stefan and A. G. Andersor, St. Anthony Falls Hydraulic Laboratory Project Report No. 69, 83 pages, April 1964.

(4200) INVESTIGATION OF THE FORCES AND INTERFERENCE

- (b) Office of Naval Research, Dept. of the Navy.
- (d) Experimental basic research.
- (e) Investigation of the lift and drag forces on the aft foil of a tandem hydrofoil configuration employing ventilated hydrofoils.
- (g) Measurements of the tandem, interference effect were made for two configurations: single foils forward and aft, and two foils forward and a single foil aft. Considerable interference was found for the former configuration, and very little interference was found for the latter configuration, even for small lateral separations of the forward foils. The downwash angle behind a ventilated foil was also measured for various lift coefficients and cavitation numbers. The downwash angle decreased monotonically with distance behind the foil.
- (h) "Tandem Interference Effects for Non-Cavitating and Supercavitating Hydrofoils," by J. M. Wetzel, St. Anthony Falls Hydraulic Laboratory Technical Paper No. 50, Series B, (in preparation).

(4201) GURI HYDROELECTRIC PROJECT MODEL STUDIES.

- (b) Harza Engineering Company, Chicago, Corp. Venezolano de Guayana.
- (d) Experimental, design and operation.
- (e) Preliminary study for the design of the Guri Hydroelectric development on the Caroni River, Venezuela using a 1:394 comprehensive spillway model, 1:197 spillway section model, and a 1:197 comprehensive model. Studies include spillway design, channel closure, and cofferdam studies.
- (h) "Guri Project River Diversion Scheme," by Lorenz G. Straub, St. Anthony Falls Hydraulic Laboratory, Jan. 1963.

(4209) THE INFLUENCE OF ELECTROKINETIC PHENOMENA ON THE HYDRAULIC AND ELECTROOSMOTIC PERMEABILITY OF UNIFORM VERY FINE SANDS.

- (b) Laboratory project.
- (d) Experimental and theoretical; Ph.D. thesis.
- (e) Accurately sized, narrow range, angular quartz particles and spherical glass beads were tightly placed in a permeameter with reversible silver-silver chloride electrodes at the ends of the test section. Streaming potential, streaming current, electrical resistivity of low conductivity liquid, and filter velocity were precisely measured. Studies include: (1) Flow retardation from return electroosmosis; (2) analysis of electroosmotic permeability factors with respect to particle characteristics and hydraulic permeability, and (3) comparisons of streaming current and filter velocity at varying Reynolds numbers.
- (g) It has been found that the streaming current-potential varies linearly with hydraulic gradient to a slightly higher Reynolds number than the filter velocity. Lack of complete deaeration causes a larger reduction in the filter velocity than the streaming. When "boiling" action takes place anomalous relations between the filter velocity and streaming current occur.
- (h) Thesis in preparation.

(4691) A STUDY OF DRAG REDUCTION BY THE USE OF NON-NEWTONIAN BOUNDARY LAYER ADDITIVES.

- (b) David Taylor Model Basin, Department of the Navy.
- (d) Experimental applied research.
- (e) A study of boundary layer mechanics and resulting shear forces for high velocity pipe flow of dilute water solutions possessing non-Newtonian characteristics.
- (f) Completed.
- (g) Wide range tests of dilute solutions of a variety of long-chain polymers show remarkable friction reductions at high shear rates as a near-laminar type of flow.
- (h) "Non-Newtonian Pipe Friction Studies with

- Various Dilute Polymer Water Solutions," by John F. Ripken and Meir Pilch, St. Anthony Falls Hydraulic Laboratory Project Report No. 71, 55 pages, June 1964.
- (4693) JET FLAPS ON SUPERCAVITATING HYDROFOILS FOR LIFT CONTROL.
- (b) Bureau of Ships, Department of the Navy.
 - (d) Experimental; basic research.
 - (e) Experimental research has been conducted in the free-jet water tunnel on supercavitating flat plate hydrofoils for the purpose of finding the effect of jet flaps on such foils.
 - (f) Completed.
 - (g) As in the non-supercavitating case, lift increment appears to be proportional to the sine of the jet-flap angle and to the square root of the jet momentum coefficient; however, the proportionality constant is materially less. There is no utility in jet flaps for ventilated supercavitated foils.
 - (h) Discussion by Edward Silberman of "The Linearized Theory of a Supercavitating Hydrofoil with a Jet Flap," by Hung-Ta Ho, Paper No. 64--FE-7, Journal of Basic Engineering, American Society of Mechanical Engineers, December 1964.
- (4696) THEORETICAL INVESTIGATION OF TWO-DIMENSIONAL UNSTEADY, SUPERCAVITATED HYDROFOIL FLOWS WITH FREE-SURFACE BOUNDARY CONDITIONS.
- (b) David Taylor Model Basin, Dept. of the Navy.
 - (d) Theoretical, basic research.
 - (e) The purpose of this research is to find the effect of free-surface on the unsteady force acting on an oscillating flat plate with a trailing cavity. Both the finite cavity case and the infinite cavity case are considered. The effect of the gravitation is also to be estimated.
 - (f) Completed.
 - (g) The force coefficient is found to consist of steady term, added mass term, and the circulatory force term. The effect of cavitation number appears linearly, but the effect of submergence appears non-linearly. The result agrees with the existing theory when the submergence is infinitely large. The force coefficient for the zero submergence case is found to be exactly one-half of that of fully wetted infinite fluid case.
 - (h) "Two-Dimensional Supercavitating Plate Oscillating Under A Free-Surface," by C. S. Song, St. Anthony Falls Hydraulic Laboratory Technical Paper No. 47, Series B, 53 pages, Dec. 1963.
- (4697) KARNAFULI PROJECT.
- (b) Agency for International Development, Dept. of State.
 - (d) Experimental; applied research.
 - (e) Experimental review of flow conditions leading to partial failure of Karnafuli Spillway.
 - (f) Completed.
 - (g) Two models of the spillway have been constructed, one a 1:132 scale comprehensive model and the other a 1:60 scale section model. Measurements have been obtained of both steady and fluctuating pressure acting on the chute and stilling basin. Data were also obtained on impact forces produced by model logs in the stilling basin and full-scale logs dropped on concrete test slabs.
 - (h) "Hydraulic Studies of Spillway for Karnafuli Hydroelectric Project, East Pakistan," by Charles E. Bowers, Frank Y. Tsai and Roy Kuha, St. Anthony Falls Hydraulic Laboratory Project Report No. 73, Sept. 1964. (Not available for distribution).
- (4698) FORCE CHARACTERISTICS OF A CAVITATING BODY IN A COMPRESSIBLE LIQUID MIXTURE.
- (b) David Taylor Model Basin, Bureau of Ships, Department of the Navy.
 - (d) Experimental, basic research.
 - (e) Investigation of the force characteristics of a cavitating body in a flowing air-water mixture.
 - (f) Completed.
 - (g) Experimental measurements were made of the drag of cavitating axisymmetric bodies in a stream of a compressible air-water mixture. As the compressibility of the mixture was increased, the drag also increased. Good agreement was obtained between the measured drag coefficient and that calculated from a modification of Gothert's rule. Some characteristics of the flow of an air-water mixture in a converging-diverging nozzle were also obtained. Choked flow and supersonic flow with weak shock waves were observed in the throat and diffuser, respectively.
 - (h) "Studies of the Flow Characteristics of a Compressible, Bubbly Mixture About Supercavitating Bodies in a Converging-Diverging Nozzle," by P. R. Schiebe, J. M. Wetzel and K. Foerster, St. Anthony Falls Hydraulic Laboratory Technical Paper No. 48, Series B, (in preparation).
- (4700) OSCILLATORY LIFT AND DRAG FORCES ON VENTILATED HYDROFOILS IN REGULAR WAVES.
- (b) Office of Naval Research, Department of the Navy.
 - (d) Experimental; basic research.
 - (e) Investigation of the force characteristics of a restrained, naturally ventilated hydrofoil moving through regular waves.
 - (g) An investigation was made of the oscillatory force characteristics of several restrained, naturally ventilated hydrofoils of finite span moving through a regular wave train. Both head and following seas were of interest. The maximum reduced frequency, based on semi-chord, was about 0.6. In general, fair agreement was obtained between quasi-steady theory and experimental data.
 - (h) "Force Characteristics of a Restrained, Naturally Ventilated Hydrofoil In Regular Waves," by J. M. Wetzel and L. T. Boyer, St. Anthony Falls Hydraulic Laboratory Project Report No. 68, (in preparation).
- (5187) VORTEX MOTION IN AN EMPTYING CONTAINER.
- (b) Laboratory project.
 - (d) The project is for a master's thesis, classified as basic research, with theoretical and experimental aspects.
 - (e) The project deals with the relationship between vortex formation at the outlet of an emptying container in relation to the vorticity in the container. The purpose is to study the formation of vortices at outlet works.
 - (f) Completed.
 - (g) The generation of a vortex at the outlet of an emptying container is related to the head on the outlet and the intensity of residual vorticity in the container. The head at which a vortex forms decreases logarithmically with time for given initial conditions.
 - (h) "A Study of Vortex Motion in an Emptying Container," by A. Ramachandra Rao, M.S. Thesis, Univ. of Minnesota, March 1964. (Available on Inter-Library Loan from the University of Minnesota Library.)
- (5188) SEDIMENT RIPPLE CHARACTERISTICS IN LOW PROUDIE NUMBER FLOW.
- (b) Laboratory project.
 - (d) Analytical, Ph.D. thesis.
 - (e) An analytical attempt to predict the length, height and shape of sediment ripples under a flow of fluid as a function of the mean parameters of the flow and of the sediment particles.
 - (f) Completed.
 - (g) A first approximation to wave shape has been determined as well as a relationship between

- wave height, length, and celerity for given flow and particle parameter.
- (h) "Characteristics of Sediment Ripples in Low Froude Number Flow," by A. G. Mercer, Ph.D. Thesis, Univ. of Minnesota, June 1964. (Available on microfilm from University Microfilms, Ann Arbor, Michigan.)
- (5493) BIG SIOUX CROSSING RIVER BRIDGE MODEL STUDY.
- (b) Iowa State Highway Commission and South Dakota State Highway Dept.
- (e) Model studies to simulate condition of failure of highway bridge due to scour and to determine method of protection and to establish procedure for prevention of scour and bank subsidence. Experiments carried out on 1:75 movable bed model.
- (5494) THERMAL POLLUTION STUDIES OF ST. CROIX RIVER.
- (b) Northern States Power Company.
- (d) Experimental.
- (e) Thermal density currents created by the discharge of heated condenser water from a steam power plant are to be studied in a model to assist in calculating the isotherm surfaces in the river. In the model, cold water is represented by salt water and warm water by fresh water. Of ultimate concern are the maximum temperatures during low water flows in summer and the extent of the ice-free region in winter. The model qualitative and highly distorted-- 1/500 horizontal and 1/30 vertical.
- (f) Model study underway.
- (5495) A STUDY OF IMPACT CAVITATION DAMAGE.
- (b) David Taylor Model Basin and Office of Naval Research, Dept. of the Navy.
- (d) Experimental applied research.
- (e) Development and tests of a cavitation damage facility utilizing repeated single liquid drop impacts on a target moving at high speed in a vacuum.
- (5496) STRUCTURE OF TURBULENCE OF NON-NEWTONIAN FLOWS.
- (b) David Taylor Model Basin, Dept. of the Navy.
- (d) Experimental, basic research.
- (e) The experiment consists of the measurements of Taylor vortices in a non-Newtonian fluid placed between two concentric cylinders when the inner cylinder is rotating.
- (5497) A STUDY OF FLOW NOISE IN A NON-NEWTONIAN FLUID.
- (b) David Taylor Model Basin, Dept. of the Navy.
- (d) Experimental.
- (e) An experimental investigation of the influence of a non-Newtonian additive on the flow noise in the boundary layer of a rotating cylinder is proposed.
- (f) Preliminary assembly of experimental equipment.
- (5498) A STUDY OF SURFACE SEALANTS TO REDUCE CAVITATION DAMAGE.
- (b) David Taylor Model Basin, Dept. of the Navy.
- (d) Experimental applied research.
- (e) A determination of materials or techniques which will serve to seal cavitating surfaces to either reduce the amount of cavitation or the damage resulting therefrom.
- (5499) INFLUENCE OF MICRO BUBBLES ON FLOW NOISE.
- (b) David Taylor Model Basin, Dept. of the Navy.
- (d) Experimental.
- (e) An experimental investigation of the flow noise intensity and spectra in the boundary layer of a rotating cylinder with the addition of free gas bubble is contemplated.
- (f) Preliminary assembly of experimental equipment.
- (5500) HYDRODYNAMIC FLUTTER OF SUPERCAVITATING HYDROFOILS.
- (b) David Taylor Model Basin, Dept. of the Navy.
- (d) Experimental, basic research.
- (e) Flat-plate hydrofoils are tested in a free-jet water tunnel at supercavitating conditions to determine the critical velocity as a function of the mass density ratio and other variables. The main purpose is to check the existing theories.
- (5501) AN ELECTROMAGNETIC VELOCITY PROBE.
- (b) A laboratory thesis study.
- (d) Experimental; M.S. thesis.
- (e) The study involves the construction, calibration and demonstration of an electromagnetic velocity probe designed for use in the study of turbulent velocity components in water flow. The magnetic field is provided by permanent magnets placed outside the flow system, which is a 3/4" ID lucite pipe. The probes are constructed of .010" platinum wire with electrode gaps of .050" and .025". A total head tube is used in conjunction with the electromagnetic probe in order to obtain mean velocities. At this time the study is in its initial stages.
- (5502) A STUDY OF BOUNDARY WALL PIEZOMETER TAP ERRORS.
- (b) A laboratory thesis study.
- (d) Analytical and experimental applied research; M.S. thesis.
- (e) A determination of the relation between the piezometer tap shape characteristics, flow boundary layer characteristics and the pressure measuring errors.
- (5503) AN EXPERIMENTAL STUDY OF THE TRANSITION FROM FULL FLOW TO OPEN CHANNEL FLOW IN A RECTANGULAR CONDUIT.
- (b) A laboratory thesis study.
- (d) Experimental; M.S. thesis.
- (e) Joints or discontinuities in the upper boundary of closed conduits may under certain flow conditions prevent the conduit from flowing completely full. In this study a smooth rectangular conduit was used with a single discontinuity in the top fixed at a given location. Full conduit flow occurred upstream from the discontinuity and open channel flow downstream from it. Water surface profiles, velocity profiles upstream and downstream from the discontinuity, and pressures were measured for various discharges and conduit slopes.
- (f) Completed.
- (g) The shape of the free water surface emerging from the discontinuity was one of two types; parallel to the upper boundary near the discontinuity and becoming convex upward as the flow spilled over the end of the conduit, or concave downward near the discontinuity and then changing to convex upward near the end. In the first case the flow was "supercritical" upstream and continued to be supercritical downstream. In the second case, the upstream flow was "subcritical" and became supercritical downstream.
- (h) "An Experimental Study of the Transition from Full Flow to Open Channel Flow in a Rectangular Conduit," by George G. Hebaus, M. S. Thesis, Univ. of Minnesota, Dec. 1964. (Available on Inter-Library Loan from the University of Minnesota Library).
- (5504) BUBBLE AERATION STUDIES.
- (b) A laboratory thesis study.
- (d) Analytical and experimental applied research; M.S. thesis.
- (e) A determination of the oxygen transferred to undersaturated water by rising clouds of submerged bubbles. Studies include variation

of bubble size, bubble concentration, water depth and oxygen deficiency.

- (5505) A STUDY OF THE WAVE ATTENUATION CHARACTERISTICS OF WATER-FILLED SPHERICAL BAGS EMPLOYED AS A FLOATING BREAKWATER.
- (b) A laboratory thesis study.
 - (d) Analytical and experimental applied research; M.S. thesis.
 - (e) A determination of the attenuation of gravity waves by rafts of water-filled spherical elastic bags floating at a free surface.
- (5506) TWO-DIMENSIONAL, INCOMPRESSIBLE, ROTATIONAL FLOW OVER A WEDGE ON THE BOTTOM OF A CHANNEL UNDER FREE SURFACE.
- (b) A laboratory thesis study.
 - (d) Theoretical; Ph.D. thesis.
 - (e) To investigate the rotational effect on the cavity and drag characteristics of the above flow over a wedge. The flow is assumed to be rotational with constant vorticity. The method is to solve the mixed boundary value problem on the upper half of the semi-infinite plane using complex variable technique.
- (5507) LINEARIZED, TWO-DIMENSIONAL, HYDRODYNAMIC THEORY FOR THE LIFT AND MOMENT ON A NON-CAVITATING HYDROFIL WITH AN OSCILLATING FLAP IN A CHANNEL OF LIMITED DEPTH.
- (b) A laboratory thesis study.
 - (d) Theoretical; Ph.D. thesis.
 - (e) The mathematical model for the hydrofoil and its wake consists of an initially unknown vortex distribution and its reflections in the free surface and the channel bottom. The velocity potential for the multiple image system is obtained from thin airfoil theory and the boundary conditions are applied to obtain a correction potential. The unknown vortex distribution is represented by a Glauert Trigonometric Series whose first four coefficients determine the lift and moment. An integral equation resulting from one of the boundary conditions is expanded in Fourier's Series and the coefficients of like terms equated, leading to an infinite set of linear inhomogeneous algebraic equations which are solved for the first four Glauert coefficients using a digital computer. The theoretical solutions are compared with experimental measurements and with the theoretical solutions for airfoils with oscillating flaps.
 - (f) Completed.
 - (g) The comparison with experimental data leads to the inference that separation effects invalidate the assumed flow model for small flap chord to foil chord ratios and that the application of the Kutta-Joukowski condition at the trailing edge is not proper. The comparison with airfoil theory shows that the quarter-chord moment coefficients may be adequately predicted from tabulated coefficients for airfoils with oscillating flaps and that the presence of the free surface reduces the lift substantially. The theory indicates that the influence of the channel bottom leads to a slight increase in the lift but that this increase is negligible for channel depths in excess of twenty foil semi-chords when the reduced frequency is high. The corresponding influence on phases and quarter-chord moments is found to be small for all channel depths considered.
 - (h) "Linearized, Two-Dimensional, Hydrodynamic Theory for the Lift and Moment on a Non-cavitating Hydrofoil with an Oscillating Flap in a Channel of Limited Depth," by William H. C. Maxwell, Ph.D. Thesis, Univ. of Minnesota, Aug. 1964. (Available on microfilm from University Microfilms, Ann Arbor, Michigan.)

INTER-AGENCY SEDIMENTATION PROJECT IN COOPERATION WITH ST. ANTHONY FALLS HYDRAULIC LABORATORY.

- (194) A STUDY OF METHODS USED IN MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS.
- (b) Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources, Personnel of the U. S. Army Corps of Engineers and the U. S. Geological Survey are actively engaged on the project.
 - (c) Engineer in Charge, Mr. Byron C. Colby, Federal Inter-Agency Sedimentation Project, St. Anthony Falls Hydraulic Laboratory, Mississippi River at Third Ave., S. E., Minneapolis, Minnesota. 55414.
 - (d) Experimental; applied research and development.
 - (e) Drawings and specifications are available to facilitate the manufacture of suspended-sediment and bed-material samplers, particle-size analyzers, and associated laboratory equipment. Approved designs for the measurement of suspended sediment include a single-stage sampler, 4-, 22-, and 62- pound depth-integrating samplers, and electrically operated point-integrating samplers weighing 100, 200, and 300 pounds. Samplers for the measurement of bed material include a piston-type hand-operated sampler, a 30-pound hand-line sampler, and a 100-pound sampler for cable suspension. Additional items are a sediment sample splitter, a bottom-withdrawal sedimentation tube for size analysis, and visual-accumulation sedimentation tubes with recording equipment for particle size analyses of sands. The primary objective of the current program is the development of an instrument to automatically record suspended-sediment concentrations in flowing streams. Field and laboratory tests have been continued on intermittent pumping-type samplers, turbidimeters and on electronic, ultrasonic and nuclear sensing devices. Field testing of the nuclear density probe was continued in 1964. An improved sedimentation chamber was installed in the ultrasonic device, and the turbidity meter was modified to use either transmitted or reflected light to measure the concentration of particles suspended in a fluid. Progress reports entitled "Electronic Sensing of Sediment" and the "Turbidity Method for Suspended Sediment Analysis" are in preparation. "Determination of Fluvial Sediment Discharge," Report No. 14, 151 pages, 1963. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 - price 70 cents per copy.

UNIVERSITY OF SOUTH CAROLINA, College of Engineering, Department of Civil Engineering.

Inquiries concerning the following projects should be addressed to Dr. Harold Flinsch, Civil Engrg. Department, University of South Carolina, Columbia, South Carolina 29208.

- (4) THE DEVELOPMENT OF SURFACE WAVES BY WIND.
- (b) Laboratory project.
 - (d) General theoretical, experimental, and field research.
 - (e) Research on the theories of surface wave origin and growth, on measurements in the laboratory and in nature, and on the comparative results of theory and measurement. Equipment has been assembled for telemetering and recording wave height, period, and direction.
 - (g) A lake shore receiving and recording station is under construction.
- (1631) THE EFFECT OF WAVES ON BEACHES.
- (b) Laboratory project.

- (d) General theoretical, experimental, and field research.
- (e) Research on beach slopes and contours, in the laboratory and in nature.
- (g) Eight-directional wave tank has been completed.

(1907) SHIP STABILITY AND ROLLING PERIOD.

- (b) Laboratory project.
- (d) General theoretical, experimental, and field research.
- (e) Rolling and pitching period and metacentric height relationships are studied for stationary and moving ships, in still water and under wave action.
- (g) Model experiments have been assembled in a brief report.

(4701) THE EFFECT OF TIDES ON HARBORS, BAYS, AND ESTUARIES.

- (b) Laboratory project.
- (d) General theoretical, experimental, and field research.
- (e) A study of the scouring or shoaling effect of tidal currents in South Carolina harbors and estuaries.

SOUTHERN METHODIST UNIVERSITY, Hydraulics Laboratory.

(5518) DESIGN, CONSTRUCTION, AND APPLICATION OF A SEEPAGE MODEL.

- (b) Laboratory project.
- (c) Assoc. Prof. Cecil H. Smith, Southern Methodist University, Dallas, Texas 75222.
- (d) Experimental; design, operation.
- (e) The design of a seepage model tank and all appurtenances. Experimental verification of the theory of seepage vs. penetration of a sheet pile wall.
- (f) Completed.
- (g) The project developed and refined equipment necessary for accurate investigation of seepage in a porous media. An experimental study was performed to check the theory of seepage quantities through and the tendency to quicksand in a homogeneous medium partially penetrated by a sheet pile cut-off wall. Results show fair agreement to seepage theory, but quick conditions are not produced where theory would indicate.

SOUTHWEST RESEARCH INSTITUTE, Department of Mechanical Sciences.

(3828) STUDIES IN HYDROELASTICITY.

- (b) Bureau of Ships, Department of the Navy (DTMB technical supervision).
- (c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Inst., 8500 Culebra Road, San Antonio, Texas 78206.
- (d) Experimental, theoretical; applied research.
- (e) Present work includes the design, construction, and testing of flexible hydrofoil models to obtain data on unsteady hydrodynamic lift and moment for a variety of operating conditions.
- (f) Completed.

(4216) STUDIES OF FUEL SLOSHING.

- (b) National Aeronautics and Space Admin., Marshall Space Flight Center.
- (c) Dr. H. N. Abramson, Director, Department of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
- (d) Theoretical and experimental; applied research.
- (e) Studies of forces and moments in missile fuel tanks resulting from sloshing motions

- of fuel.
- (h) "Some Measurements of the Effects of Ring Baffles in Cylindrical Tanks", by H. N. Abramson and L. R. Garza, AIAA Journal of Spacecraft and Rockets, in press. "Some Measurements of Liquid Frequencies and Damping in Compartmented Cylindrical Tanks", by H. N. Abramson and L. R. Garza. AIAA Journal of Spacecraft and Rockets, in press.

(4217) LIQUID DYNAMIC BEHAVIOR IN ROCKET TANKS.

- (b) National Aeronautics and Space Administration, Washington, D. C.
- (c) Dr. H. N. Abramson, Director, Department of Mechanical Sciences, Southwest Research Inst., 8500 Culebra Road, San Antonio, Texas 78206.
- (d) Theoretical and experimental; applied research.
- (e) Current interest is concerned with nonlinear aspects of lateral sloshing.

(4702) HYDRODYNAMICS OF SHIP ANTI-ROLL TANKS.

- (b) Bureau of Ships, Department of the Navy (DTMB technical supervision).
- (c) Mr. John F. Dalzell, Senior Research Engineer, Department of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
- (d) Theoretical and experimental; applied research.
- (e) Studies of forces and damping effects in passive anti-roll stabilization tanks for ships.
- (h) One Southwest Research Institute technical report.

(4704) VIBRATION OF HYDROFOIL STRUCTURES.

- (b) Bureau of Ships, Department of the Navy (DTMB technical supervision).
- (c) Mr. Jack T. Irick, Senior Research Engineer, Department of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
- (d) Theoretical and experimental; applied research.
- (e) Study of the vibration characteristics of hydrofoil-type structures.

(4926) LIQUID FREE SURFACE NEAR ZERO G.

- (b) National Aeronautics and Space Administration, Marshall Space Flight Center.
- (c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
- (d) Theoretical; applied research.
- (e) Analysis of liquid free surface shape for very small values of gravity.
- (f) Completed.
- (h) "An Analysis of the Quasi-Steady Liquid-Gas Interface in an Axisymmetric Tank During Low Gravity Transfer", by Wen-Hwa-Chu. Final Report, Contract NAS 8-5468.

(4927) LIQUID DYNAMIC BEHAVIOR IN TANKS UNDER AXIAL OSCILLATION.

- (b) National Aeronautics and Space Administration, Marshall Space Flight Center.
- (c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
- (d) Theoretical and experimental; applied research.
- (e) Studies of nonlinear liquid motions in rigid and elastic tanks undergoing axial oscillations.
- (h) Four Southwest Research Institute technical reports.

(4928) FLUTTER ANALYSIS OF HYDROFOILS.

- (b) U. S. Navy, Bureau of Ships.
 - (c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
 - (d) Theoretical; applied research.
 - (e) Calculations of flutter speed for a hydrofoil flutter model by several different techniques.
 - (h) Two Southwest Research Institute technical reports.
- (5266) HYDROELASTIC STUDIES OF SUPERCAVITATING HYDROFOILS.
- (b) Bureau of Ships, Dept. of the Navy.
 - (c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
 - (d) Theoretical and experimental; applied research.
 - (e) Design, construction, and testing of dynamic supercavitating hydrofoil models to obtain data on unsteady hydrodynamic lift and moment for a variety of operating conditions.
- (5267) MONOGRAPH ON LIQUID DYNAMIC BEHAVIOR IN ROCKET PROPELLANT TANKS.
- (b) National Aeronautic and Space Administration, Washington, D. C.
 - (c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
 - (d) Theoretical; applied research.
 - (e) Preparation of a monograph on stated subject.
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- STANFORD UNIVERSITY, Department of Civil Engineering.
- (1946) HYDROLOGIC SYNTHESIS.
- (b) National Science Foundation.
 - (c) Prof. Ray K. Linsley and N. H. Crawford, Dept. of Civil Engineering, Stanford Univ., Stanford, Calif. 94305.
 - (d) Theoretical and field research.
 - (e) Detailed digital computer synthesis models are used to investigate the interaction of physical variables in the hydrologic cycle.
 - (g) A simplified mathematical treatment of non-equilibrium overland flow has been developed. Digital computer programs to simulate non-equilibrium overland and channel flow in rivers and streams have been developed. A statistical analysis of soil-moisture frequency has been completed. Synthesis models which calculate continuous streamflow from rainfall, temperature, and potential evapotranspiration data have been developed and application of these models to ungaged areas is being studied together with related applications for engineering design.
 - (h) "A Conceptual Model of the Hydrologic Cycle," by N. H. Crawford and R. K. Linsley, publication No. 33, Int. Assn. of Scientific Hydrology, Symposium on Surface Waters, pp. 573-587.
- "The Synthesis of Continuous Snowmelt Runoff Hydrographs on a Digital Computer," E. A. Anderson and N. H. Crawford, Technical Report No. 36, Dept. of Civil Engineering, Stanford University, June 1964.
- (2151) MODEL STUDY OF PETERS DAM CHUTE SPILLWAY.
- (b) Laboratory project.
 - (c) Prof. John K. Vennard, Dept. of Civil Engrg., Stanford University, Stanford, Calif. 94305.
 - (d) Experimental; engineer thesis.
 - (e) Comparison of spillway performance and design predictions.
 - (f) Discontinued.
- (2614) PIPE FRICTION IN UNSTEADY FLOW.
- (b) Laboratory project.
 - (c) Prof. John K. Vennard, Dept. of Civil Engineering, Stanford University, Stanford, Calif. 94305.
 - (d) Experimental and analytical; Ph.D. thesis.
 - (e) Comparison of friction processes for steady and unsteady states.
 - (f) Completed.
 - (g) Experimental work completed and analyzed.
 - (h) Report now available.
- (3507) STUDY OF INFILTRATION.
- (b) U. S. Public Health Service.
 - (c) Prof. Joseph B. Franzini, Dept. of Civil Engineering, Stanford University, Stanford, California 94305.
 - (d) Theoretical investigation; laboratory and field studies; basic research; Ph.D. theses.
 - (e) An attempt is being made to develop relations between soil parameters and infiltration capacities. Investigation is being extended to unsteady unsaturated flow through soils as experienced in capillary rise, drainage, and infiltration situations.
 - (g) An analytic approach to the solution of unsteady unsaturated flow in soils has been developed. If the initial moisture condition and the hydraulic and capillary characteristics of the soil are known, the method permits prediction of the future disposition of soil moisture. Experiments using a gamma source for moisture content have been conducted.
 - (h) "A Method of Analyzing Unsteady, Unsaturated Flow in Soils," by F. C. Wang, N. A. Hassan, and J. B. Franzini, Jnl. of Geophysical Research, Vol. 69, pp. 2569-2577, June 1964.
- "The Influence of Capillarity on the Flow of Air and Water in a Porous Medium," by Donald Dean Adrian, Technical Report No. 38, Dept. of Civil Engineering, Stanford University, 1964.
- (4219) SUPERCAVITATING HYDROFOIL THEORY.
- (b) David Taylor Model Basin, Bureau of Ships, Navy Department.
 - (c) Professors R. L. Street and B. Perry, Dept. of Civil Engrg., Stanford Univ., Stanford, Calif. 94305.
 - (d) Theoretical, basic research for Ph.D. theses and post-doctoral research.
 - (e) Examination is being made of forces acting on fully cavitating bodies. Effects of free surfaces, gravity, angle of attack, rotation, etc. are being studied. Linearized, non-linearized and finite-difference numerical analyses are conducted.
 - (g) Rotation, gravity, free surface and tandem interference effects between bodies have been shown to have important roles in fully cavitating flows.
 - (h) "A Note on Gravity Effects in Supercavitating Flows," by R. L. Street, Stanford U. Civil Engineering Dept. Tech. Rep. No. 32, Mar. 1964.
- "A Nonlinear Theory for Symmetric, Supercavitating Flow in a Gravity Field," by C. V. Lenau and R. L. Street, to appear J. Fluid Mech., 1964.
- (4705) HYDRAULICS OF OPEN CHANNELS.
- (b) Laboratory Project.
 - (c) Prof. Joseph B. Franzini Stanford Univ., Stanford, Calif. 94305.
 - (d) Theoretical investigation and experimental program; Ph.D. theses.
 - (e) Several aspects of open-channel flow are under investigation including (1) velocity and shear distribution in open channels having different cross-sectional shapes, (2) characteristics of flow in a channel that simulates the cross-section of a river. In particular, the case where supercritical flow in the main channel section changes to subcritical flow in the overbank-stage section is being investigated.

- (f) Analytic approach to (1) and (2) are underway.
- (4706) INVESTIGATION OF THIN-FILM LIQUID FLOW OVER SOLID BODIES OF DIFFERENT SHAPE.
- (b) Laboratory project.
 - (c) Prof. Joseph B. Franzini, Stanford Univ., Stanford, Calif. 94305.
 - (d) Theoretical and experimental investigation; Ph.D. thesis.
 - (e) The characteristics of thin-film liquid flow over solid bodies (spheres, ellipsoids, cones, cylinders, and composites) are being investigated. In later stages of the research it is anticipated that the results from flow over single bodies will be applied to packings so that the research can be extended to the hydraulics of trickling filters.
 - (f) Preliminary analysis for thin-film liquid flow over spheres and ellipsoids has been completed.
 - (h) "Hydraulics of Thin Film Flow," by J. B. Franzini and N. A. Hassan, Jnl. of Hydraulics Division, American Society of Civil Engineers, HY 2, pp. 23-36, March 1964.
- "Film Flow Along a Vertical Cylinder," by N. A. Hassan and J. B. Franzini, Jnl. of Engineering Mechanics, American Society of Civil Engineers, EM 4, pp. 23-35, Aug. 1964.
- (4707) FREE SURFACE FLOW OVER SPILLWAYS.
- (b) Laboratory project.
 - (c) Prof. R. L. Street, Dept. of Civil Engr., Stanford Univ. Stanford, Calif. 94305.
 - (d) Theoretical, basic research for doctoral thesis.
 - (e) Analytic methods are being developed to determine the shape of the free surface on and up-stream of spillway. Small experimental program to be carried on to verify analytic results.
 - (f) Completed.
 - (g) Complex variable analysis has produced method for predicting free surface shape, flow velocities and pressures for varying bottom configurations.
 - (h) "Two-Dimensional Flow Over Sills in Open Channels," by G. Z. Watters and R. L. Street, J. Hydr. Division, Proc. ASCE, V. 90, No. HY4, July 1964.
- (4916) DISPERSION OF POLLUTANTS IN FLOW THROUGH POROUS MEDIA.
- (b) Laboratory project.
 - (c) Prof. E. Y. Hsu and R. L. Street, Dept. of Civil Engrg, Stanford Univ., Stanford, Calif. 94305.
 - (d) Basic experimental and theoretical research for Ph.D. thesis.
 - (e) Study of hydrodynamic dispersion in porous media. Complex variable analysis of flow fields is combined with a convective dispersion equation to define time-space history of pollutant concentrations. Effects of channel boundary shapes and free streamlines on dispersion are to be studied also.
 - (g) Theoretical and experimental analyses in progress.
- (4917) MECHANISMS INVOLVED IN WIND-GENERATED WAVES.
- (b) Fluid Mechanics Branch, Math. Sci. Div., Office of Naval Research.
 - (c) Prof. E. Y. Hsu and R. L. Street, Dept. of Civil Engrg., Stanford Univ., Stanford, Calif. 94305.
 - (d) Experimental and theoretical basic research for doctoral theses.
 - (e) Examination, experimental verification, and extension of available theory are the purpose of this project. A steady flow model of the wind-wave problem is being constructed in the laboratory.
- (5453) STUDIES OF LARGE WAVES.
- (b) Laboratory project.
 - (c) Prof. R. L. Street, Dept. of Civil Engrg., Stanford Univ., Stanford, Calif. 94305.
 - (d) Experimental investigation; master's and Ph.D. project.
 - (e) Study of and verification of theory regarding characteristics of large waves-breaking, shoaling, and run-up. Wave-shore interaction. Facility under construction.
- (5454) STUDIES ON WIND-WAVE INTERACTIONS.
- (b) National Science Foundation.
 - (c) Prof. E. Y. Hsu, Dept. of Civil Engrg., Stanford Univ., Stanford, Calif. 94305.
 - (d) Experimental; Ph.D. theses.
 - (e) Basically experimental program to study the interface and particle motion in air and water at boundary between water waves and blowing wind. Development of appropriate flow parameters and experimental verification of their significance in wind-wave generation process and growth prediction. Facility under construction.
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- STEVENS INSTITUTE OF TECHNOLOGY, Davidson Laboratory.
- (2154) INVESTIGATION OF HIGH SPEED SHIP FORMS.
- (b) ONR and BuShips, Dept. of the Navy.
 - (c) Prof. Earl M. Uram, Davidson Laboratory, Stevens Institute of Technology, 711 Hudson Street, Hoboken, N. J.
 - (d) Theoretical and experimental; basic research.
 - (e) Investigation of hydrodynamic and motion characteristics of high speed ship forms for supercritical operation in search of considerable improvement of seakeeping qualities and powering requirements.
 - (f) Completed.
 - (g) A study of the feasibility, design, and experimentally determined performance of an unusual shallow running, high speed submersible incorporating a surface piercing dihedral hydrofoil system was investigated. Above 35 knots the ship is found superior to the conventional destroyer and other unusual ship forms regarding horsepower requirement and response to wave systems.
 - (h) "Study of the Design and Behavior of a Hydrofoil Semi-Submarine," by E. M. Uram, Report 1023, August 1964.
- "Behavior of Unusual Ship Forms," by E. M. Uram and E. Numata. Presented at ONR Fifth Symposium on Naval Hydrodynamics, Sept. 1964.
- (2155) SEAKEEPING QUALITIES OF SHIPS AT ALL HEADINGS TO WAVES.
- (b) David Taylor Model Basin, Bureau of Ships, Department of the Navy.
 - (c) Mr. E. Numata, Davidson Laboratory, Stevens Institute of Technology, Castle Point Station, Hoboken, N. J.
 - (d) Experimental; applied research.
 - (e) To investigate wave exciting forces and moments acting on a restrained ship model running at oblique headings to regular waves.
 - (f) Completed.
 - (g) Oscillatory components and steady mean components of sway force, yaw moment, heave force, and pitch moment were measured on a Series 60, $C_D = 0.60$ ship model running at three forward speeds and five headings to regular waves of five lengths. Forces and moments varied only slightly with forward speed; mean components of pitch and yaw moments were about 15% of corresponding oscillatory components. Good agreement was shown between strip theory calculations and experimental yaw moment and sway force measurements.
 - (h) "Experimental Determination of Wave Excited Forces and Moments Acting on a Ship Model Running in Oblique Regular Waves," Y. Chey, Davidson Laboratory Report 1046.

- (3516) INVESTIGATION OF HULL BENDING MOMENTS IN WAVES OF EXTREME STEEPNESS.
- (b) Ship Structure Committee.
 - (c) Mr. Edward Numata, Davidson Laboratory, Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J.
 - (d) Experimental; applied research.
 - (e) Model tests were carried out to determine vertical hull bending moments in very steep waves using a model of a Mariner cargo ship cut transversely at five equally spaced sections within the midship half-length; two longitudinal weight distributions were tested in head and following seas.
 - (g) Wave bending moment at each section is generally proportional to wave height up to a wave height/wave length ratio of 1/9. Maximum moments occur within the midship quarter length.
 - (h) "Investigation of Bending Moments Within the Midship Half-Length of a Mariner Model in Extreme Waves," N. M. Maniar, SSC Report 163.
- (4226) INVESTIGATION OF SURFACE-PIERCING FULLY VENTILATED DIHEDRAL HYDROFOILS.
- (b) Office of Naval Research, Department of the Navy.
 - (c) Mr. P. Ward Brown, Chief of High Speed Craft Division, Davidson Laboratory, Stevens Inst. of Tech., 711 Hudson Street, Hoboken, New Jersey.
 - (d) Experimental and theoretical; applied research.
 - (e) A continuing investigation aimed at providing basic design information on three-dimensional hydrofoils operating near a water surface, under conditions of either fully wetted or fully ventilated flow. To date the forces and moments on a series of surface piercing dihedral hydrofoils have been measured and the dynamics of systems employing such foils has been studied, including the problem of a hydrofoil impacting on the water surface and the stability of hydrofoil craft, and their response in waves.
 - (g) Analytical expressions for the forces and moments on surface piercing fully wetted and fully ventilated dihedral hydrofoils, including the effect of flaps, have been obtained and confirmed experimentally. Unsteady problems including those of stability, impact and ventilation of such foils have also been dealt with. The conventional linearized supercavitating foil theory has been extended to cover the entire angle of attack range with simplicity and precision. The response of surface piercing hydrofoil systems in irregular waves has been analyzed and techniques developed and proved experimentally for making predictions of the time history of motion response in irregular waves.
 - (h) "Deterministic Predictions of the Motions of a Hydrofoil Craft in Irregular Seas," R. P. Bernicker, DL Report 1003, Jan. 1964.
"The Force, Moment, and Hinge-Moment Characteristics of Surface-Piercing Dihedral Hydrofoils," R. P. Bernicker and P. W. Brown, DL Report 964, May 1964.
"Effect of Flaps on the Lift and Drag of a Surface-Piercing, Fully Ventilated Dihedral Hydrofoil," Gerard Fridsma, DL Report 978, November 1964.
- (4227) SMOOTH WATER BEHAVIOR OF SURFACE-PIERCING HYDROFOIL VESSEL.
- (b) Office of Naval Research, Fluid Dynamics Branch, Navy Dept.
 - (c) Dr. A. Strumpf, Head Underwater Weapons Div., Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J.
 - (d) Theoretical and experimental; applied research.
 - (e) An experimental and theoretical study is being made of the smooth water operation of a 110-ton craft supported by a tandem set
- of surface-piercing hydrofoils. The aim of the study is to develop equations of motion and obtain the hydrodynamic data necessary to permit the behavior of the boat to be predicted in the case of coupled six degrees of freedom motions. Previous work has been restricted mainly to the study of the pure pitching and heaving motions. Solution of the motion equations developed in the theoretical part of this report required that the hydrodynamic damping force and moment rate coefficients (Y'_p , N'_p and K'_p) be evaluated. These quantities could not be determined from the experiments, so a set of formulae based upon available theory were developed for this purpose. In addition, formulae were also developed for predicting the static force and moment rate coefficients (Y'_p and N'_p). These rates were used to substantiate the values determined experimentally and to lend assurance to the methods used for prediction.
- Solutions to a linearized set of the original motion equations were obtained via the use of a digital computer. The three part program written for the UNIVAC 1105 computer establishes the pitch plane equilibrium conditions, calculates the zeroes of the decoupled yaw and pitch plane equations, and calculates a running trajectory for the craft. At the present time, these calculations are being completed and the results analyzed.
- (g) The experimental results show that the lift developed by the rear foil is reduced appreciably by the presence of the forward foil. The rear foil also ventilates under design conditions. For the first time a number of hydrodynamic derivatives with respect to turning angular velocity were obtained from the experimental test results.
 - (h) Progress Reports may be obtained through Correspondent.
- (4228) FLUTTER OF HYDROFOILS ON FLEXIBLE STRUCTURES.
- (b) David Taylor Model Basin, Bureau of Ships, Dept. of the Navy.
 - (c) Mr. Charles J. Henry, Research Engineer, Davidson Laboratory, Stevens Inst. of Tech., Hoboken, N. J.
 - (d) Theoretical; basic research.
 - (e) Since hydrofoil flutter appears to be possible and since a flutter accident may be dangerous, a thorough investigation of this phenomenon is needed involving the use of a realistic theoretical model. A first step in this direction is the study of the hydroelastic instability of a hull-appendage configuration by means of the assumed modes or Rayleigh-Ritz method of vibration analysis. Completed.
 - (f) Equations of motion were derived for the free vibrations of an elastic beam with a foil-shaped appendage. Unsteady hydrodynamic effects on the foil have been taken into account by two-dimensional unsteady flow theory, applied in a stripwise fashion, whereas the hydrodynamic loads on the hull were reduced to the added mass effect. Computer programs were developed to predict the decay rate and frequency of this system in up to six degrees of freedom.
 - (h) "Hydroelastic Study of Elastic Beams with a Foil-Shaped Appendage," C. J. Henry and M. R. Ali, DL Report 1022, July 1964.
- (4229) THE BOUNDARY LAYER UNDER PROGRESSIVE AND STANDING WAVES.
- (b) Office of Naval Research, Dept. of the Navy.
 - (c) Dr. S. J. Lukasik, Chief, Fluid Physics Division, Davidson Laboratory, Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J.
 - (d) Experimental, theoretical, and field investigations; basic research.
 - (e) The purpose of this work is to study energy loss processes in shallow water waves.

- Theoretically, this is of interest because unsteady viscous flows have received relatively little attention, particularly the case of an oscillatory flow with no mean flow. Analytical and numerical solutions of the non-linear Navier-Stokes equations are under investigation. Laboratory measurements in the Stevens shallow water wave channel have been made of the wave attenuation coefficient of a progressive wave, the bottom shear stress under a progressive wave, and the time decay of standing waves. Field measurements of the bottom pressure and bottom velocity in 40 foot depths have been made off Block Island, R.I. These field measurements provide the possibility of determining the applicability of the laboratory measurements and the theoretical studies to the geophysical problem of the energy loss by ocean waves in shallow coastal waters.
- (g) Direct measurement of the wave attenuation coefficient both at Stevens and MIT indicated that the energy dissipation in a shallow water gravity wave exceeded that which would be expected from a linearized laminar solution of the Navier-Stokes equation valid in the bottom boundary layer. Several hypotheses have been examined in order to reconcile the discrepancy. It appears that the cause of the excess attenuation lies in the fact that the finite amplitude nature of the wave potential flow must be considered when formulating the boundary layer problem. For small deviations from infinitesimal amplitude theory, the Stokes approximation is valid. The attenuation theory, when revised to include the effect of the first two harmonics as well as the fundamental frequency, is then in much better agreement with the laboratory measurements of the attenuation. Oceanographic studies to relate the theory and laboratory work on the attenuation of gravity waves to the case of ocean swell are continuing.
- (h) "Wave Boundary Layers - Theory," C. E. Grosch.
 "Wave Boundary Layers - Experiments," S. J. Lukasik.
 Papers presented at the Symposium on Dye Diffusion in Oceans and Fresh Waters, Lamont Geological Observatory, 31 August - 2 September 1964. Proceedings to be published by Oceanographic Society of Japan.
- (4711) STUDY OF THE PROPELLER SINGING PHENOMENON.
- (b) David Taylor Model Basin, Office of Naval Research, Dept. of the Navy.
 (c) Dr. Jumpei Shioiri, Visiting Scientist from Tokyo Univ., and Dr. S. Tsakonas, Head of Fluid Dynamics Division, Davidson Laboratory, Stevens Institute of Technology, 711 Hudson St., Hoboken, New Jersey.
 (d) Theoretical; applied research.
 (e) To study the propeller singing phenomenon as a self-excited vibration system composed of the Karman vortex-shedding mechanism and the propeller blade.
 (f) Completed, final report in preparation.
 (g) A model for the propeller singing phenomenon based upon the self-excited version was presented to interpret the step and jump characteristics in the singing frequency versus flow velocity diagram. The different elements of the "closed loop" of the self-excited vibrational system are presented and discussed. Stability criteria derived from the synchronized run of the shedding mechanism, together with the positive work criteria imposed upon the phase relation between the blade vibration and hydrodynamic reaction of the shed vortices give a reasonable interpretation for the step and jump characteristics.
- (5057) UNSTEADY LIFTING SURFACE THEORY FOR A MARINE PROPELLER OF LOW PITCH ANGLE WITH CHORDWISE LOADING DISTRIBUTION.
- (b) David Taylor Model Basin, Bureau of Ships, Dept. of the Navy.
 (c) Dr. S. Tsakonas, Head of Fluid Dynamics Div., and W. R. Jacobs, Senior Research Engineer, Davidson Laboratory, Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J.
 (d) Theoretical; applied research.
 (e) The purpose is to solve the surface integral equation for a mathematical model with chordwise loading based on the first term of Birnbaum's distribution and to apply the results to the problems of vibratory thrust and torque of a marine propeller and far-field pressure signal from the propeller when it is moving in non-uniform inflow.
 (f) Completed.
 (g) The integral equation is solved for a mathematical model where the chordwise loading is taken as the first term of Birnbaum's lift distribution (flat plate) in conjunction with Glauert's lift operator. It is shown that this model is an improvement over the modified Weissinger model used previously in this series because it contains as a nucleus the exact two-dimensional solution and thus it provides a sounder basis for determining the three-dimensional effects. The blade loading is determined for a propeller operating in flow disturbances induced by the presence of a hull, blade camber and incidence angle. Calculations are made for the propeller vibratory thrust and torque and conclusions are drawn on the dependence of loading on the important parameters--blade-area ratio, aspect ratio and propeller pitch.
- (h) Tsakonas, S. and Jacobs, W. R., "Unsteady Lifting Surface Theory for a Marine Propeller of Low Pitch Angle with Chordwise Loading Distribution," Davidson Laboratory Report 994, January 1964, Accepted for publication in the Journal of Ship Research.
- (5058) UNSTEADY LOADS ON TEED HYDROFOILS IN OBLIQUE SEAS.
- (b) Bureau of Ships, Dept. of the Navy.
 (c) Dr. S. Tsakonas, Head of Fluid Dynamics Div., and Mr. Charles J. Henry, Research Engineer, Davidson Laboratory, Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J.
 (d) Experimental and theoretical; basic research.
 (e) To investigate the forces and moments acting on hydrofoil struts and foils while operating in oblique regular waves.
- (5059) THREE DIMENSIONAL GUST PROBLEM IN THE PRESENCE OF A FREE SURFACE.
- (b) Laboratory project.
 (c) Dr. S. Tsakonas, Head Fluid Dynamics Div., and Mr. Charles J. Henry, Research Engineer, Davidson Laboratory, Stevens Institute of Tech., 711 Hudson Street, Hoboken, N. J.
 (d) Theoretical, basic research.
 (e) The kernel function is derived which relates the normal velocity to the load distribution on a thin oscillating wing of arbitrary configuration moving near a free surface in three dimensional flow. This kernel function is developed in such a way that the resulting integral equation is amenable to numerical solution.
 (f) Completed.
 (g) The kernel function of the surface integral equation, which relates the unknown loading with the known downwash distribution on a hydrofoil of arbitrary orientation moving near the free surface, is derived. Limiting forms of the kernel at high and low Froude numbers are expressed in analytical forms. The two-dimensional counterpart of the kernel for the finite Froude number case agrees with the results previously obtained by other investigators. Solution of the integral equation for the case of a flat plate of finite aspect ratio moving near the free surface at high Froude number is discussed.

- (5060) UNSTEADY LIFTING SURFACE THEORY FOR A MARINE PROPELLER OF AN ARBITRARY PITCH ANGLE WITH CHORDWISE LOADING DISTRIBUTION.
- (b) David Taylor Model Basin, Bureau of Ships, Dept. of the Navy.
 - (c) Dr. S. Tsakonas, Head of Fluid Dynamics Div., and C. Y. Chen, Research Engineer, Davidson Laboratory, Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J.
 - (d) Theoretical; applied research.
 - (e) To solve the surface integral equation relating the unknown loading distribution on the propeller blade lying on a helicoidal surface of an arbitrary pitch with the known velocity distribution induced by the presence of a hull, without resorting to any mathematical simplification.
- (5062) EFFECT OF PLANFORM VARIATIONS ON HYDROFOIL FLUTTER.
- (b) Bureau of Ships, Dept. of the Navy.
 - (c) Mr. Charles J. Henry, Research Engineer, Davidson Laboratory, Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J.
 - (d) Experimental and theoretical; basic research.
 - (e) Measurements of flutter speed were obtained for a two degree of freedom system including the effects of sweep, taper and aspect ratio. The results were compared with predictions using two-dimensional stripwise theory and will be compared with three-dimensional lifting surface theory.
 - (g) Two-dimensional strip theory prediction of flutter speed did not agree with measured values for a 15° swept foil nor for two tapered foils with taper ratios of 2/3 and 1/3. The asymptotic behavior of flutter speed at low density ratio remains in the two degree of freedom system even with sweep and/or taper and is not accurately predicted by two-dimensional strip theory. The measured flutter speed on a foil with rectangular planform increased with decreasing aspect ratio.
- (5064) INVESTIGATION OF SHIP MOTIONS.
- (b) U. S. Naval Training Devices Center, Dept. of the Navy.
 - (c) Prof. Earl M. Uram, Staff Scientist, Davidson Laboratory, Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J.
 - (d) Theoretical and experimental; basic research.
 - (e) Development of equations of motion of ships in very low speed maneuvering condition to be applied to a simulator for training.
 - (g) Analysis of general linearized motion equations including terms of importance at very low speeds. Experimental model and full scale program to determine static and dynamic derivatives of importance for inclusion in computer programs for calculating responses to bridge commands.
- (5065) A STUDY OF SHIP FORMS AT HIGH FROUDE NUMBERS.
- (b) Office of Naval Research, Dept. of the Navy.
 - (c) Dr. Hajime Maruo, visiting scientist from Univ. of Yokohama, and Mr. King Eng, Research Engineer, Davidson Laboratory, Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J.
 - (d) Theoretical; applied research.
 - (e) To evolve, develop and evaluate new concepts and modifications for surface and near surface ship forms for the attainment of high speeds and good seakeeping qualities in calm and rough water.
 - (f) Completed.
 - (g) Using the slender body theory as a guide, a ship of DD692 Destroyer class was designed and tested in the Davidson Laboratory. Compared to the results of the DD692 Destroyer, it has excellent seakeeping qualities for all wave lengths investigated. However, the calm water resistance is higher at low speed, but lower at high speed.
 - (h) Report in preparation.
- (5309) ESTIMATION OF STABILITY DERIVATIVES AND INDICES OF VARIOUS SHIP FORMS, AND COMPARISON WITH EXPERIMENTAL RESULTS.
- (b) David Taylor Model Basin, Office of Naval Research, Dept. of the Navy.
 - (c) Miss Winnifred R. Jacobs, Research Engr., Davidson Laboratory, Stevens Institute of Technology, 711 Hudson Street, Hoboken, N. J.
 - (d) Theoretical; applied research.
 - (e) An analytical method is devised for estimating stability derivatives which combines Albring's empirical modifications of simplified flow theory with aerodynamic wing theory. The method is then checked by comparing calculated derivatives with those computed from experimental data obtained in rotating-arm tests.
 - (f) Completed.
 - (g) Comparison with experimental results in 35 cases, including two families of hulls of 8 members each, show that the stability derivatives and indices determined by the analytical method are of the right order of magnitude and indicate correct trends. The method can predict relative effects of changes in ship form geometry and effects of changes in skeg and rudder area.
 - (h) "Estimation of Stability Derivatives and Indices of Various Ship Forms and Comparison with Experimental Results," W. R. Jacobs, Davidson Laboratory Report 1035, September 1964.
- (5310) ACOUSTIC PROPERTIES OF BUBBLES IN PRESSURE FIELDS.
- (b) David Taylor Model Basin, Bureau of Ships.
 - (c) Prof. E. M. Uram, Staff Scientist, and J. W. Hollenberg, Research Engineer, Davidson Laboratory, Stevens Institute of Technology, Castle Point Station, Hoboken, N. J.
 - (d) Experimental, theoretical; basic research.
 - (e) Study of the sound produced by a single gas bubble in the presence of boundaries generating a varying pressure field in the flow direction. Also to be included is the effect of bubble interference on radiated sound.
- (5311) STRUCTURE OF TURBULENT WAKES WITH ASYMMETRIES.
- (b) David Taylor Model Basin, Bureau of Ships.
 - (c) Prof. E. M. Uram, Staff Scientist, Davidson Laboratory, Stevens Institute of Technology, Castle Point Station, Hoboken, N. J.
 - (d) Experimental; basic research.
 - (e) Determination of turbulent structure of wakes very near bodies of revolution with systematically varied asymmetries. Particular attention to distortion imposed by asymmetries and circumferential eddy structure.
- (5312) INVESTIGATE GAIN IN WATER SPEED OBTAINED BY COUPLING AMPHIBIOUS CRAFT.
- (b) Office of Naval Research, Dept. of the Navy.
 - (c) Mr. Howard Dugoff, Assistant Chief, Vehicle Research Division, or Mr. Robert L. Van Dyke, Research Engineer, Davidson Laboratory, Stevens Institute of Technology, Castle Point Station, Hoboken, N. J.
 - (d) Experimental investigation; applied research. The purpose of the study is to investigate the gain in water speed that can be obtained by coupling several amphibious vehicles end-to-end. Towing tank tests are being performed with six wooden scale models of the LVT5 tracked amphibian to establish the drag characteristics per vehicle while increasing the number of units. Operation of both individual and coupled vehicles in waves of reasonable size ranging from head to quarter to following seas is also being studied.
 - (g) No major results have yet been obtained.
- (5313) HYDRODYNAMIC TRACK PROPULSION.
- (b) Office of Naval Research.

- (c) Mr. Howard Dugoff, Assistant Chief, Vehicle Research Div., Davidson Laboratory, Stevens Institute of Technology, Castle Point Station, Hoboken, N. J.
- (d) Experimental and theoretical investigations; applied research.
- (e) The purpose of the study is to investigate the mechanism by which floating land vehicles propel themselves through water by use of their tracks only. Towing tank tests are being conducted using a non-operating track section. A theoretical performance analysis of the test configuration is also being made for comparison with the experiments. The results of this initial program are intended to provide data for the optimum design of an operating track model to be built and tested in a subsequent study.
- (g) No major results have yet been obtained.
- (5314) HYDRODYNAMIC WHEEL PROPULSION OF FLOATING LAND VEHICLES.
- (b) U. S. Army Tank Automotive Center.
- (c) Mr. Howard Dugoff, Assistant Chief, or H. M. Parekh, Research Engineer, Vehicle Research Div., Davidson Laboratory, Stevens Institute of Technology, Castle Point Station, Hoboken, N. J.
- (d) Experimental investigation; applied research.
- (e) The fluid dynamic mechanism by which a floating land vehicle can propel itself through water by spinning its fully submerged wheels is being investigated. Studies are being conducted on two related yet essentially distinct aspects of the problem:
Phase 1 Hydrodynamic Studies of Spinning Disk. Tests are being conducted to determine the thrust force which acts on a disk rotating about an axis parallel to a plane boundary. The experiments are being performed for comparison with a proposed theoretical solution, reported on in last year's issue (reference number 5067), intended to provide an insight into the basic elements of the wheel propulsion phenomenon.
Phase 2 Tests on Scale Model of Floating Cargo Truck. Towing tank tests of self-propelled scale model of a five ton army cargo truck are being conducted for investigation of its wheel propulsion characteristics. The tests closely parallel experiments performed previously at another laboratory. However, because of the paramount importance of viscous effects in the wheel propulsion phenomenon, they are based on a Reynolds number scaling law rather than the Froude number law used in the previous tests.
- (g) Phase 1. The experimental results follow the trends predicted by the theory. In general, however, the measured values of thrust are lower than the theoretical predictions. It is felt that this may be due primarily to deficiencies inherent in the available apparatus and in the test setup employed. Thus additional tests with an improved setup are planned.
Phase 2. No major results have yet been obtained.
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- TEXAS A AND M UNIVERSITY, Department of Oceanography and Meteorology.
- (4866) MODIFICATION OF TWO-DIMENSIONAL LONG WAVES OVER VARIABLE BOTTOM TOPOGRAPHY.
- (b) Coastal Engineering Research Center, DA-49-055-CIV-ENG-63-9.
- (c) Prof. R. O. Reid, Texas A and M Univ., College Station, Texas.
- (d) Theoretical applied research.
- (e) The objective is to investigate the modification of free gravity waves in variable depth, including reflection and transmission aspects, with particular attention being given to the interaction of tsunamis with islands. The analysis employs numerical methods.
- (g) Modified long wave equations have been developed for taking vertical acceleration and dispersive character of waves into account. A system of development of an orthogonal coordinate system for an island of general configuration is being investigated which will facilitate numerical analysis of the wave field. In this system, the island contour represents a given value of one of the coordinates, while in the far field the coordinates reduce to a simple polar or cartesian form (depending upon the method of analysis).
- (h) "Variation Formulation for Long Waves in Variable Depth," by R. O. Reid and A. C. Vastano. Presented at national meeting of the American Geophysical Union, April 1963.
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- TEXAS A & M UNIVERSITY, Water Resources Institute.
- Inquiries concerning the following projects should be addressed to Dr. Ernest T. Smerdon, Director, Water Resources Institute, Texas A and M University, College Station, Texas.
- (5477) THE MECHANICS OF EROSION BY FLOWING WATER.
- (b) Texas A & M University.
- (d) Experimental; basic and applied.
- (e) The study is to determine relationships between water erosion of soils and the hydraulic characteristics of the flowing water, to develop quantitative relationships between specific soil properties and an acceptable erosion index, and to develop design data by which the erosion hazard can be adequately considered in the design of water control and management systems.
- (g) Laboratory research has been carried out in the research flume on channel erosion and sediment transport with shallow flow, both with and without simulated rainfall. The effects of soil compaction on soil erosion have been studied in the flume. Chemical and mineralogical data are available on the soils. In addition, a rotating shear apparatus has been constructed and tests performed to measure the erosion character of soils in this laboratory device under carefully controlled conditions. The effect on erosion resistance of changing the cations on the clay are being studied in this apparatus.
- (h) "Erosion of Soils Under Shallow Flow With and Without Simulated Rainfall," by W. L. Bathke. M. S. Thesis, Texas A&M University, May 1963.
"The Effect of Void Ratio on Critical Tractive Force in Cohesive Soils," by W. M. Lyle. M.S. Thesis, Texas A&M University, January 1964.
"Relation of Compaction and Other Soil Properties on Erosion Resistance of Soils," by W. M. Lyle and E. T. Smerdon. Trans. American Society of Agricultural Engineers, (in press).
"Study of the Effect of Sediment Transport on Stability of Open Channels," by K. M. A. Rahman. M. S. Thesis, Texas A&M University, January 1963.
"Critical Shear Stresses in Cohesive Soils," by R. J. Rektorik. M. S. Thesis, Texas A&M University, January 1964.
"Critical Tractive Forces in Cohesive Soils from a Rotating Shear Apparatus," by R. J. Rektorik and E. T. Smerdon. Paper No. 64-212, American Society of Agricultural Engineers Annual Meeting, Fort Collins, Colorado, June 21-24, 1964.
"Effect of Rainfall on Critical Tractive Forces in Cohesive Soils," by E. T. Smerdon. Trans., American Society of Agricultural Engineers, Vol. 7, No. 3, pp 287-290, 1964.
"Flume Studies of Erosion Resistance of Soils," by E. T. Smerdon. Paper presented at Texas Section of the American Society of Civil Engineers, College Station, Texas,

April 17, 1964.

"Effect of Water Layer Thickness on Impact Force of Water Droplets on a Soil Surface," by M. R. Biswas and E. T. Smerdon, Dept. Technical Report No. 1, Agricultural Engineering Department, Texas A&M University, August 1964.

(5478) WATER POLLUTION FROM ERODED SEDIMENTS.

- (b) Texas A&M University.
- (d) Experimental; basic and applied.
- (e) The laboratory study is designed to obtain data on the initial transport of eroded sediments from the point of detachment to streams of appreciable size. This transport path considered, which may be only a few hundred feet to a few miles, is that portion of the flow path which is sufficiently shallow to be significantly affected by the existence of rainfall energy on the flow. This stream size limit is unknown but will be determined and related to rainfall energy and other factors affecting the flow and sediment transport capability of the flow.
- (f) Initiated September 1, 1964.

(5479) EFFECT OF SURFACE IRRIGATION HYDRAULICS ON EFFICIENT APPLICATION OF WATER.

- (b) Texas A&M University.
- (d) Laboratory and field investigation.
- (e) The objectives are to determine the effect of irrigation stream size, slope and shape of irrigated surface, hydraulic roughness of irrigated surface, and water intake characteristics of soil on irrigation system design for most efficient application of water by surface irrigation methods; and to correlate results into design procedures, using hydraulic factors of surface irrigation as criteria for design.
- (g) The results indicate that it may be possible to integrate the differential equation for the advance and recession curves by single graphical means (rather than by lengthy and cumbersome numerical calculations or using computers). This will make specific design practical for individual farms and soil conditions instead of so-called "rule-of-thumb" designs so often used now.
- (h) "Irrigation Efficiencies" by E. T. Smerdon. Paper presented at the Trans-Pecos Cotton Production Conference, Pecos, Texas, February 15, 1963.
"Subsurface Water Distribution in Surface Irrigation," by E. T. Smerdon. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 89, pp. 1-15, March 1963.
"Surface Irrigation Water Distribution Efficiency Related to Soil Infiltration," by E. T. Smerdon and L. J. Glass. Trans., American Society of Agricultural Engineers (in press).
"Relationship Between the Rate of Advance and Intake Rate in Furrow Irrigation," by E. T. Smerdon and C. M. Hohn. Texas Agricultural Experiment Station Misc. Pub. 509, April 1961.
"Water Distribution Along Surface Irrigation Runs," by E. T. Smerdon, C. M. Hohn, J. S. Newman and E. L. Thaxton, Jr. Texas Agricultural Experiment Station Prog. Rpt. 2275, May 1963.
"Solution of the Irrigation Advance Problem," by Otto Wilke and E. T. Smerdon, paper presented at ASCE Irrigation and Drainage Specialty Conference, El Paso, Texas, Dec. 1964.

UNIVERSITY OF TEXAS, Department of Civil Engineering.

Inquiries concerning Projects Nos. 2162, 2397, 3524, 4234, 4235, 4715, 5456 and 5457 should be addressed to Dr. Walter L. Moore, Department of Civil Engrg., Univ. of Texas, Austin 12, Texas.

(2161) CHARACTERISTICS OF A HYDRAULIC JUMP AT AN ABRUPT CHANGE IN BOTTOM ELEVATION.

- (b) University of Texas Research Institute and Bureau of Engineering Research.
- (c) Dr. Carl W. Morgan, Assoc. Prof. of Civil Engineering, Univ. of Texas, Austin, Texas.
- (d) Experimental.
- (e) Experimental determinations were made of the flow characteristics at two-dimensional channel drops and rises. The velocity distribution and surface profile were determined throughout the length of the jump for various relative changes in bottom elevation. The longitudinal location of the jump in relation to the change in bottom elevation was varied over a broad range in contrast with previous related investigations in which relative location of the jump was held constant.

(2162) HYDROLOGIC STUDIES, WALLER CREEK WATERSHED.

- (b) Cooperative with U. S. Geological Survey.
- (d) Field investigation; applied research.
- (e) Measurements of rainfall and runoff for a 4 square mile and a 2 square mile portion of the Waller Creek watershed are being made to provide basic information for estimating runoff from small urban watersheds in the Southwest area. Two stream flow stations and a rain gage net are in operation. Studies of the correlation between runoff, rainfall, and the characteristics of the drainage basin are being made by various proposed methods to serve as a base for comparison with the data as it is collected from the stream.
- (g) The records are now long enough to begin comparing with peak discharge estimates previously given at least for short recurrence intervals. A start is being made on this analysis.

(2397) EFFECT OF UPSTREAM DEVELOPMENT ON THE RUNOFF FROM SMALL WATERSHEDS IN THE SOUTHWEST.

- (b) Laboratory project.
- (d) Field investigation (thesis).
- (e) For selected watersheds rainfall runoff relations are being developed on a storm by storm basis. Multiple correlation diagrams, based on data before changes in the watershed, have been developed and used to compute runoff for later periods. Comparison of these computed runoff values with measured values is taken as an index of the effect of watershed development.
- (g) The first results were not conclusive because of random error in the computed values. Further studies are being made on another watershed with an improved method which better accounts for the spacial variation of rainfall.

(2874) AN INVESTIGATION OF THE SCOUR RESISTANCE OF COHESIVE SEDIMENTS.

- (b) The University of Texas Research Institute.
- (c) Dr. Frank D. Masch, Department of Civil Engineering, The University of Texas, Austin 12, Texas.
- (d) Analytical and experimental (laboratory).
- (e) Exploratory tests have been made with two different schemes, one with radially outward flow between a circular disc and the soil sample, and one with a submerged vertical circular jet impinging on a horizontal soil surface. With the first scheme it was not possible to obtain the necessary precision of measurement at low scour rates, but with the second scheme satisfactory measurements were obtained. A correlation based on dimensional analysis gave consistent results in evaluating the relative scour resistance of several materials. Apparatus has been fabricated for a new test which permits direct evaluation of the shear stress at the soil

surface. In this test a cylindrical soil sample is submerged in a transparent concentric cylinder which can be rotated at a controlled speed to generate a shear stress on the soil surface. Attempts are being made to relate the scour resistance to other measurable soil properties, and finally to interpret the results in relation to field observations.

- (g) The apparatus to determine shear stress at the soil surface has been constructed and calibrated, a test procedure has been developed, and tests have been conducted on soil samples.

(3522) LONG TIME FLUCTUATIONS IN STREAM RUNOFF.

- (b) Laboratory project.
- (c) Dr. Carl W. Morgan, Dept. of Civil Engrg., Univ. of Texas, Austin 12, Texas.
- (d) Analytical and field study.
- (e) Values of runoff from selected drainage areas in the lower Mississippi River Basin and in basins of the rivers emptying directly into the Gulf of Mexico were studied. Variations in the runoff values for each stream were considered and these trends compared with solar variations. The relative sunspot numbers were used as the measure of solar variations and were correlated with the mean annual runoff. Further correlations are being made with different "lag" periods between solar activity and surface runoff.
- (g) The gradual shifting of the centers of runoff excess and deficiency is consistent rather than random and appears to represent a gradual cyclic change in the runoff pattern. It appears that the locations of the centers of runoff deficiency are following roughly the same path that they did some 22 to 24 years previously. Correlation coefficients of plus 0.2 to plus 0.5 are obtained for selected rivers in Mississippi, Alabama, Georgia, and Arkansas when sunspot numbers in the 11-year sunspot cycle are correlated with runoff. Texas streams do not give significant correlation with the 11-year sunspot cycle but give better correlation if runoff is compared with the double sunspot cycle in which sunspot numbers are assumed as negative in alternate cycles.

(3524) GROUND WATER FLOW AND SEEPAGE IN NON-HOMOGENEOUS, NON-ISOTROPIC SEDIMENTS.

- (b) Laboratory project.
- (d) Theoretical, basic.
- (e) A relaxation solution for the Laplace equation has been developed which is applicable across a boundary between two regions of different permeabilities. It is believed that the method can be expanded to apply to any specified non-homogeneous and non-isotropic condition. It is intended that the solution be set up for computation on an electronic computer and that selected numerical solutions be checked against those from an electrolytic tank.

(4234) EVAPORATION REDUCTION BY CONTROL OF ADVECTED ENERGY.

- (b) Partial sponsorship by the Lower Colorado River Authority of Texas.
- (d) A Master's thesis involving theoretical and field investigation.
- (e) Measurements have been made to determine the temperature field in Lake Travis for the 1962-63 season. A method was developed to estimate the effect of withdrawing water from near the lake surface. Monthly estimates of the resulting temperature field and reduction in evaporation were made.

(4235) TWO-PHASE FLOW IN CONDUITS.

- (b) Laboratory project.
- (d) Experimental master's thesis.

- (e) It is apparent that for a two-phase flow system with a liquid and gas, many different types of flow are possible. This investigation explored the use of sound measurements to detect the type of flow present, in a metal pipe. Various types of flow were established in a thin-walled aluminum pipe, 1.66 I.D., with a transparent plastic section at each end. Records of the sound pattern were made with different pick-ups and correlated with the visual observation of the flow type. Magnetic tape records of the sound were also made.
- (g) Study of the recorded sound patterns revealed some identifiable characteristics related to the type of two-phase flow in the line. Additional work is needed to refine techniques and try other sound pick-up and recording methods.

(4716) DRAG FORCES IN VELOCITY GRADIENT FIELDS.

- (b) David Taylor Model Basin, Dept. of the Navy.
- (c) Dr. Frank D. Masch and Dr. Walter L. Moore, Department of Civil Engineering, The Univ. of Texas, Austin 12, Texas.
- (d) Theoretical and experimental; basic research.
- (e) The investigation is being conducted to determine the effect of a velocity gradient on the local and conventional drag coefficients for cylinders of varying L/D ratio and at different Reynolds Numbers. The study will be extended to other shapes.
- (g) Preliminary studies have demonstrated that the velocity gradient along a cylinder affects the drag coefficient. The local drag coefficient decreases along the cylinder in the direction toward the end of the cylinder where the velocity is high. The reduction in drag coefficient is related to a dimensionless measure of the velocity gradient along the cylinder.
- (h) "Drag Forces in Velocity Gradient Fields", Charles Dalton and Frank D. Masch, Hydraulic Engineering Laboratory Technical Report No. HYD 04-6401, The University of Texas, March 1964.
"Separation in a Non-Uniform Shear Flow", Charles Dalton and Frank D. Masch, Hydraulic Engineering Laboratory Technical Report No. HYD 04-6402, The University of Texas, Sept. 1964.

(4717) TWO-FLUID FLOW IN A POROUS MEDIUM.

- (b) Bureau of Engineering Research, Univ. of Texas.
- (c) Dr. L. R. Mack, Department of Civil Engineering, Univ. of Texas, Austin 12, Texas.
- (d) Theoretical; basic research for masters thesis.
- (e) The velocity distribution within and the shape of the interface between two immiscible fluids of different densities flowing through a uniform isotropic porous medium toward a well is sought. This problem is of interest in both petroleum engineering and ground-water hydrology.
- (g) A method has been devised for satisfying the governing equations, including the non-linear boundary conditions at the interface. This method which is also applicable to axisymetric flow, is now being applied to the two-dimensional case.

(4990) WAVE CHARACTERISTICS IN SHOALING WATER.

- (b) Coastal Engineering Research Center, Corps of Engineers.
- (c) Dr. Frank D. Masch, Dept. of Civil Engrg., The Univ. of Texas, Austin 12, Texas.
- (d) Theoretical; basic and applied research.
- (e) This study is to develop a workable method for computing water wave characteristics in shoaling water using cnoidal wave theory. The method involves evaluating the power transmission for a wave train in shallow water from cnoidal theory and using the

- concept of constant power between
orthogonals on a refraction diagram.
- (g) Integrals of the cnoidal functions have been evaluated in terms of elliptic integrals and computer programs have been developed to solve the resulting equations.
- (h) "Application of Cnoidal Wave Theory to the Transformation of Long Waves," Frank D. Masch. Hydraulic Engineering Laboratory Technical Report No. HYD 05-6401, The Univ. of Texas, Jan. 1964.
- (4991) LOCAL SCOUR IN CHANNELS.
- (b) Laboratory project.
- (c) Dr. Frank D. Masch and Dr. Walter L. Moore, Dept. of Civil Engrg., The Univ. of Texas, Austin 12, Texas.
- (d) Theoretical and experimental; basic and applied research.
- (e) This project is designed to investigate the characteristics of the three dimensional flow patterns at channel obstructions and to study the extent to which these flows affect local scour. It is believed that a more thorough understanding of the fundamentals of the flow at an obstruction would provide the basis to devise methods for controlling scour. The nature of scour at culverts is also under consideration with efforts being devoted to develop methods for dissipating energy and reducing local scours.
- (5455) HYDROLOGY OF SMALL URBAN WATERSHEDS.
- (b) Bureau of Engineering Research, Texas Water Commission.
- (c) Dr. Carl W. Morgan, and Dr. Frank D. Masch, Dept. of Civil Engineering, The Univ. of Texas, Austin 12, Texas.
- (d) Field investigation, basic research.
- (e) Data from selected watersheds have been collected. These are being studied to evaluate the effects of urbanization on the hydrologic characteristics of the watersheds.
- (g) For the Waller Creek Watersheds, Austin, Texas preliminary results indicate that because of approximately twice as high percent of impervious cover in the lower part it produced yields per unit area approaching twice that of the upper area.
- (5456) MATHEMATICAL MODELS FOR RELATING RUNOFF TO RAINFALL.
- (b) Laboratory project.
- (d) Doctoral thesis based on computer analysis of field data.
- (e) The study is presently aimed at determining the runoff hydrograph from the rainfall data for individual storms. A computer solution to a multiple correlation method is used to obtain the amount of runoff for successive time intervals for individual sub areas of the watershed, and a modified unit hydrograph approach is used to obtain the runoff hydrograph at the lower end of the watershed. Preliminary results indicate that the method will be useful to estimate storm hydrographs where rainfall data are available for a long time, and flow records are available for only a short period. It is hoped that additional correlations can be developed for base flow making it possible to build up continuous runoff hydrographs based on rainfall records.
- (g) Preliminary results indicate good success in predicting runoff hydrographs for individual storms.
- (5457) A NEW TYPE ENERGY DISSIPATOR FOR CULVERT OUTLETS.
- (b) Laboratory project.
- (d) Experimental and theoretical doctoral thesis.
- (e) A study is being made of a culvert energy dissipator based on the use of a sector of a circular hydraulic jump. Apparent advantages of the device are the stability of the jump over a range of discharge and tailwater conditions and the opportunity to spread the culvert discharge back to the original stream width. Problems of practical geometry need to be explored to see what compromises can be made and still achieve satisfactory energy dissipation performance.
- (5458) SEDIMENTATION IN GALVESTON-TRINITY BAYS.
- (b) Texas Parks and Wildlife Commission and Department.
- (c) Dr. Frank D. Masch, Dept. of Civil Engrg., Univ. of Texas, Austin 12, Texas.
- (d) Experimental, field; applied research.
- (e) Field investigation to determine the currents, sources of sediment, and sediment movement in Galveston and Trinity Bays, and to determine the effect they may have on the dredging of mudshell, oysters and oyster production.
- (5459) FINITE-AMPLITUDE GRAVITY WAVES.
- (b) Laboratory project.
- (c) Dr. L. R. Mack, Dept. of Engineering Mechanics, Univ. of Texas, Austin 12, Texas.
- (d) Theoretical, basic research for master's thesis and doctoral dissertation.
- (e) In order to obtain better quantitative agreement with the experimental frequency determinations of Pultz and of Edge, the analytical solutions for both two-dimensional standing waves and axisymmetric standing waves are being carried to the fifth order in amplitude. Velocity distribution, free-surface configuration, and frequency of oscillation are being obtained.
- (5460) WIND WAVE OVERTOPPING OF SHORELINE STRUCTURES.
- (b) Bureau of Engineering Research, Univ. of Texas, Austin 12, Texas.
- (c) Dr. Frank D. Masch, Dept. of Civil Engrg., Univ. of Texas, Austin 12, Texas.
- (d) Experimental, thesis.
- (e) This study is designed to compare overtopping from wind waves with that predicted from criteria based on uniform wave trains. Overtopping is being measured under varying wind and wave conditions. Particular study is being given to beach geometry immediately in the front of the structure and its effect on overtopping rates.
- (g) Results obtained to date show that the greater the depth of water at the wall, the greater the overtopping rates. The offshore beach profiles appear to have little or no effect on overtopping from wind generated waves.
- (5461) ANALYSIS OF UNIT HYDROGRAPHS FOR SMALL WATERSHEDS.
- (b) Laboratory project.
- (c) Dr. Carl W. Morgan, Dept. of Civil Engrg., The Univ. of Texas, Austin, Texas.
- (d) Field investigation, thesis.
- (e) Characteristic, two-hour unit hydrographs were determined for each of three selected watersheds. The derived dimensionless hydrograph shapes were compared with two widely-used empirical hydrographs. Techniques were studied for using the S-curve hydrograph as an aid in estimating the correct duration of rainfall excess by selecting that duration which caused the least fluctuation in the S-curve.
- (g) The dimensionless 2 hour unit hydrographs developed in this study indicate that the falling limbs of the Commons and Mockus hydrograph shapes may need revision in order to be applied to watersheds of less than 100 square miles in area. However, these differences are only minor

suggesting that an average dimensionless graph and reliable estimates of only two parameters, period of rise and peak discharge may be sufficient to define the shape of the unit hydrograph. Results indicate the S-curve can be used to estimate by trial and error the rainfall excess duration if rainfall data is not available.

- (h) "Analysis of Unit Hydrographs for Small Watersheds in Texas," Wilbur L. Meier Jr., M.S. Thesis, The University of Texas, August 1964.

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(5197) SPECIAL PROBLEMS IN FLUID DYNAMICS.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. A. Ritter, President, Therm Advanced Research, Inc., 100 Hudson Circle, Ithaca, N. Y.
- (d) Theoretical basic research.
- (e) This is a continuing project of analytical studies which to date have consisted of:
 - (1) The Hydrodynamics of Free-Surface Crossings, concerned with predicting the hydrodynamic forces acting on bodies in vertical motion crossing an air-water interface, and includes examination of the accuracy of the standard assumptions of infinite Froude number and small disturbances; and (2) The Jet-Flap Hydrofoil Near a Free Surface, a study which will provide expressions for the forces and moments acting on a two-dimensional jet-flap hydrofoil in close proximity to a free surface as well as determining the depth of submergence at which free-surface effects may be neglected.
- (f) (e) 1. Completed, 2. Active.
- (g) A second-order, small-perturbation theory for the water-exit and -entry of slender symmetric bodies, including Froude number and air-density effects, has been developed.
- (h) "Image Solution for Vertical Motion of a Point Source Towards a Free Surface," by John P. Moran, Journal of Fluid Mechanics, Vol. 18, Part 2, pp. 315-320, 1964.
 "Addendum: The Vertical Water-Exit and -Entry of Slender Symmetric Bodies," by John P. Moran, AIAA Journal, Vol. 2, No. 8, pp. 1480-1482, August 1964.
 "On the Hydrodynamic Theory of Water-Exit and -Entry," by John P. Moran, Therm Advanced Research, Inc. Technical Report. (In prep.)

(5198) THE LOW-ASPECT-RATIO JET-FLAP HYDROFOIL.

- (b) David Taylor Model Basin, Dept. of the Navy.
- (c) Mr. Gary R. Hough, Staff Scientist, Therm Advanced Research, Inc., 100 Hudson Circle, Ithaca, N. Y.
- (d) Theoretical basic research.
- (e) The objective of this project is to develop a theory which will predict satisfactorily the forces and moments acting on a fully wetted, low-aspect-ratio jet-flap hydrofoil.
- (f) Terminated.
- (g) The conventional Jones low-aspect-ratio approximation has been applied to the governing lifting-surface equation for a jet-flap hydrofoil and a solution obtained. Deficiencies are apparent, especially for a deflected jet (singular blowing) and a rectangular platform. As a result, the improved low-aspect-ratio approximation of Lawrence is investigated, the governing equation derived for this case, and a tentative procedure for solution advanced and discussed.
- (h) "On the Theory of the Low-Aspect-Ratio Jet-Flap Hydrofoil," by J. C. Erickson, Jr. and G. R. Hough, Therm Advanced Research, Inc., TAR-TR 6405, October 1964.

UTAH STATE UNIVERSITY, College of Engineering.

(3183) DYNAMICS OF FLOW IN STEEP, ROUGH, OPEN CHANNELS.

- (b) Laboratory and field project; Rocky Mt. Exp. Sta.; U. S. Forest Service; Nat'l Sci. Found.
- (c) Dr. Dean F. Peterson, Dean of Engineering, Utah State University, Logan, Utah 84321.
- (d) Experimental, theoretical, field investigation; basic research for doctoral theses.
- (e) A basic study of relationships involved in flow in steep, rough channels where the roughness is relatively an appreciable part of the depth, and where channels are sufficiently steep or steeper than a slope such that supercritical flow can occur in connection with contractions caused by the roughness. The work is basic, however, it will have application to steep mountain streams and to hydraulic structures. The objective of the work is to relate descriptive parameters describing the size and configuration of the bed roughness to slope, depth and discharge of channels of this class. Studies began using simple bar and cube elements and have progressed through the use of beds formed by gluing natural gravel elements of various size, gradation and intensity to the bed. Nineteen field sites have been installed in streams, principally in northern Utah in the Wasatch Mountains, but also in New Mexico and Colorado. Piezometric type stilling wells have been installed at several sites and discharge and depth measured. Bed element distribution and size have been studied at all sites. A laboratory model study of scouring and paving of high-gradient streams under a constant discharge was completed. Flume studies are continuing using natural-gravel elements glued to the beds in order to attempt to delineate Reynold's numbers effects and to study velocity distribution. For the bed paving studies, a bed of graded sand and gravel was placed in the flume at a preselected slope and allowed to scour under constant discharge until scouring equilibrium occurred. This was repeated for several discharges and three sizes of sand and gravel. Cross sections and slope were accurately measured and samples were taken of the elements in the paved bed. The final size of the bed elements was related to the discharge and the final slope size correlates well with data for similar non-cohesive materials from canals using tractive force equations, even though discharges and slopes differ by orders of magnitude. The relationship $f(Q/d_{50} V, S) = 0$, in which d_{50} is the final mean bed size, V is the Kinematic viscosity, and S the slope is proposed. The correlations of the forms $W = aQ^b$, $D = cQ^f$, and $V = pQ^m$ where W is water surface width, D is mean depth, and V is mean velocity, Q is discharge, and a, b, c, f, p, m are constants as proposed by Leopold and Mattock were consistent with field data of others. It was not possible to maintain stable beds for $F = V/\sqrt{gD} > 1$ increasing the slope of the flume increased scour and the formation of combination bed elements sometimes in the shape of transverse bars prevented further increase in Froude's number. It is suggested that this condition would be one of minimum energy density per unit weight of water. As stable slope increased W/D decreased and bed-element size increased.
- (h) "Relation Between the Bed Pavement and the Hydraulic Characteristics of High Gradient Channels in Noncohesive Sediments," by Davoud Hariri. Ph.D dissertation, Utah State University, Logan, Utah, 1964, 109 p.
 "A Study of Bed Characteristics in Relation to Flow in Rough, High-Gradient, Natural Channels," by Earl E. Judd. Ph.D Dissertation, Utah State University, Logan, Utah, 1963, 182 p.

- (3185) HYDRAULICS OF SURFACE IRRIGATION.
- (b) Public Health Service.
 - (c) Dr. Vaughn E. Hansen, Director, Utah Water Research Laboratory, Utah State Univ., Logan, Utah. 84321.
 - (d) Experimental, theoretical; basic research; Doctoral dissertation.
 - (e) Hydrodynamic and field study of movement of water over a porous surface when intake varies with time. The free surface and the rates of advance are defined.
 - (g) Differential equations have been developed which define the free surface and rates of advance. High speed computers have been used to obtain typical solutions which have been compared with field measurement of the rate of advance. The results are within ten percent of field observations. A dimensionless plot has been constructed which will predict the advance for any given set of known soil conditions. A companion study is based upon utilizing empirical relationships as a foundation for subsequent development of rate of advance functions. The results compare well with measured values.
 - (h) "The Theory and Characteristics of Overland Flow," by Cheng-lung Chen and Vaughn E. Hansen. Publication pending ASAE 1964.
- (3528) THE EFFECT OF SEDIMENT PROPERTIES ON THE ATTENUATION OF AN ULTRASONIC PLANE WAVE.
- (b) National Science Foundation.
 - (c) Dr. Gordon H. Flammer, Civil and Irrigation Engineering Department, Utah State Univ., Logan, Utah 84321.
 - (d) Theoretical and experimental; basic research.
 - (e) Some theoretical and experimental work has been performed on the attenuation of an ultrasonic plane wave passing through a sediment suspension. However, experimental work is still very limited in scope, particularly over certain loss regions. This study uses a standard pulse technique to investigate a wide range of natural and manufactured sediments over the various loss ranges. Of primary concern is the effect of the various sediment properties on the attenuation.
 - (g) Natural sediments have been completed and an MS thesis has been prepared giving the results. Manufactured sediments of known properties have been tested, and a PhD dissertation has been completed and is available at the Utah State University Library.
 - (h) "The Effect of Sediment Properties on the Attenuation of an Ultrasonic Plane Wave," by Norman E. Stauffer, Jr. PhD dissertation, Utah State University, Logan, Utah, 1964.
- (3530) WATER REQUIREMENTS OF MARSHLANDS.
- (b) Utah State Fish and Game Dept.
 - (c) Prof. Jerald E. Christiansen, Professor of Civil and Irrigation Engineering, Utah State Univ., Logan, Utah. 84321.
 - (d) Field investigations; applied research, Master's theses.
 - (e) Large areas of marshy lands adjacent to Great Salt Lake have been developed and improved by the State Fish and Game Dept., and the Federal Wildlife Service, as Migratory Bird Refuges. Available stream flow from several of the major streams flowing into these areas where the water is impounded behind dikes to create habitat suitable for nesting, feeding and resting of water fowl. Millions of ducks and geese utilize this area each year during their migratory flights.
 - (f) Field work completed, final report under preparation.
 - (g) The basic purpose of the study is to determine the quantities of water necessary for marshlands in order to maintain them in a productive state.
 - (h) Eight progress reports have been written. Three MS theses and one PhD dissertation have been completed.
- (3845) WATERSHED MODEL STUDIES.
- (b) Agricultural Research Service, U. S. Dept. of Agriculture.
 - (c) Dr. Jay M. Bagley, Civil and Irrigation Engineering, Utah State University, Logan, Utah 84321.
 - (d) Experimental; basic research for Master's and Doctoral theses.
 - (e) The purpose is to establish techniques and model-prototype laws so that watersheds can be intensively studied in a laboratory. A small watershed has been modeled. A rainfall simulator has been constructed for which design or actual rainfall events can be programmed to occur automatically over the model. The dominant factors influencing the characteristic shape of the run-off hydrography are being studied. Initial efforts have been aimed at determining effect on modeling relationships resulting from changes in the physical properties of water-chemical mixtures used in the rainfall simulator. Test runs are being made using a physical model with an impervious surface. Subsequent tests will incorporate the relationship between infiltration and run-off by providing for permeability changes in the model.
 - (g) Satisfactory mechanical performance and electronic control has been achieved. Verification tests to date are highly encouraging. Experimental tests are continuing.
- (4236) METHODS FOR PREDICTING MEAN ANNUAL WATER YIELDS IN UTAH.
- (b) Utah Water and Power Board.
 - (c) Dr. Jay M. Bagley, Civil and Irrigation Engineering Dept., Utah State University, Logan, Utah 84321.
 - (d) Experimental; applied research.
 - (e) This work was undertaken to develop methods of obtaining economical and reasonably accurate determinations of watershed yield where stream gaging records are not available. Certain relatively easily obtained parameters characterizing the physical and climatic factors have been correlated with water yield for a number of watersheds having good records of stream flow.
 - (f) Completed.
 - (g) Regression equations have been developed for estimating water yield from physical characteristics of basins in various regions of Utah. Based on the developments of this study, a water yield map for the entire state of Utah is being prepared. The map, equations and graphs should aid materially in broadening the coverage of hydrologic information needed for first stage planning of a long range state-wide nature.
 - (h) "Water Yields in Utah," by J. M. Bagley, R. W. Jeppson, and C. H. Milligan. Special Report No. 18, Utah State University and Utah Water and Power Board, September 1964.
- (4719) FREE SURFACE FLOW AROUND A HEMISPHERICAL ROUGHNESS ELEMENT.
- (b) Laboratory project.
 - (c) Dr. Gordon H. Flammer, Associate Professor, Civil and Irrigation Engineering Dept., Utah State University, Logan, Utah 84321.
 - (d) Experimental and theoretical research toward a Master's thesis.
 - (e) This study was made to gain further information on flow characteristics (primarily drag) around a hemispherical roughness element where the element size is of the order of the depth of the free surface flow. To accomplish this, water surface data, velocity profile data and primarily drag data was taken for a range of Froude numbers. The thesis attempts to answer certain questions concerning the effects on a single large hemispherical roughness element in open channel flow. Of particular interest is the flow condition where the element has an effect on the fluid surface configuration.

- An M.S. thesis has been prepared on this project. This work, however, is considered to be only preliminary to a continued study of much wider proportions.
- (g) The results of this investigation may be summarized as follows: (1) The drag force on the hemisphere is due primarily to wave drag in the Froude number range 0.35 to 2.50 and for submergence intervals y/k up to 1.2. (2) At a given submergence interval the coefficient of drag decreases as the Froude number of 1.5 for all submergence intervals. This constant value is approximately 0.2. (3) The drag coefficient increases with an increase in submergence in the Froude number range up to 1.5. (4) The relationship between the coefficient of drag and the Froude number tends to become linear as the submergence increases.
- (5129) CALIBRATION OF IRRIGATION HEADGATES BY MODEL ANALYSIS.
- (b) D.M.A.D. Irrigation Companies, Delta, Utah.
 (c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
 (d) Experimental; applied research.
 (e) The D.M.A.D. Irrigation Companies have approximately 600 of these headgates in their distribution system and would like to use the headgate as a measuring device. Standards for the installation of such a headgate will be developed along with flow rate curves and tables.
 (f) Completed.
 (g) A general method of analysis was developed for rating submerged gates. The coefficient of discharge of the system was markedly affected by the degree of relative submergence. Also, the location of the gate guide angles, whether facing upstream or downstream, affected the coefficient of discharge by 12 percent.
 (h) "Calibration of Irrigation Headgates by Model Analysis," by Gaylord V. Skogerboe and Vaughn E. Hansen. Report PR-EC50-1, Engineering Experiment Station, Utah State University, Logan, Utah, March 1964. "Rating Submerged Gates for Flow Measurement in Open Channels," by Gaylord V. Skogerboe, American Society of Agricultural Engineers. (Publication pending; available upon request.)
- (5130) FARM IRRIGATION STRUCTURES.
- (b) Laboratory project.
 (c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
 (d) Library research.
 (e) A compilation of the material pertaining to the design of small irrigation structures that would be found on a farm. Will also determine gaps in information which will require additional research.
- (5131) A STUDY OF THE STRUCTURE AND EDDY DIFFUSIVITY OF TURBULENT SHEAR FLOWS IN ROUGH OPEN CHANNELS.
- (b) Laboratory project.
 (c) Dr. Calvin G. Clyde, Civil Engineering Dept., Utah State Univ., Logan, Utah 84321.
 (d) Experimental and theoretical; basic research for Ph.D. Thesis.
 (e) To describe the structure of the turbulence in turbulent shear flows in rough open channels; to see if local isotropy exists in the turbulence under study; and to investigate the relationship of the structure of the turbulence to the process of diffusion in the flow. The necessary instrumentation has been developed and the experimental and analytical work is proceeding.
- (5132) TECHNIQUES OF AERIAL APPLICATION OF EVAPORATION-REDUCING MATERIALS TO LARGE LAKES AND RESERVOIRS.
- (b) U. S. Bureau of Reclamation.
 (c) Dr. Vaughn E. Hansen, Director, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
 (d) Experimental; applied research and development.
 (e) Development of equipment and techniques for the aerial application of monolayer-forming materials.
 (g) The performance of the equipment has been very satisfactory. Techniques have been developed for the use of alcohols in molten form and the use of powdered alcohols. Further research and development will be concerned only with powdered alcohols.
 (h) "Aerial Application of Evaporation Retardants to Water Surfaces," by Vaughn E. Hansen and Gaylord V. Skogerboe. Agricultural Aviation 6(4): 113-120, 1964. "Equipment and Techniques for Aerial Application of Evaporation-Reducing, Monolayer-Forming Materials to Lakes and Reservoirs," by Vaughn E. Hansen and Gaylord V. Skogerboe, Utah Water Research Laboratory, Utah State University, Logan, Utah, 1964. (Available upon request.)
- (5133) UTAH STATE UNIVERSITY STILLING BASIN FOR PIPE TO OPEN CHANNEL FLOW.
- (b) Laboratory project.
 (c) Dr. Gordon H. Flammer, Assoc. Prof. Civil and Irrigation Engr. Dept., Utah State University, Logan, Utah 84321.
 (d) Experimental research has been completed for one Master's thesis and is being performed for a second thesis.
 (e) The objective of this study is to find an economical and effective means of energy dissipation at the transition of pipe flow to open channel flow.
 (g) An effective design has been found involving a short dissipator pipe placed on the opposite wall of the stilling basin from the inflow pipe. The best ratios have been found for: the dissipator pipe diameter to inflow pipe diameter, length of dissipator pipe to inflow pipe diameter, slit width to inflow pipe diameter, and center line offset to the inflow pipe diameter. The second MS thesis is studying the effect of changing the inlet pipe diameter and the inlet pipe velocity on the most efficient design described above.
 (h) An MS thesis has been completed and research toward the second MS thesis is being actively pursued. The results of these two theses will be prepared for publication in a professional journal.
- (5134) CHARACTERISTICS OF THE SURFACE WAVE CAUSED BY VARIOUS SUBMERGED OBJECTS IN OPEN CHANNEL FLOW AND THEIR RELATIONSHIP TO THE DRAG ON THE OBJECT.
- (b) Laboratory Project (An NSF grant has been applied for).
 (c) Dr. Gordon H. Flammer, Assoc. Prof. of Civil and Irrigation Engineering Dept., Utah State University, Logan, Utah 84321.
 (d) Theoretical and experimental work leading toward a doctoral dissertation.
 (e) The characteristics of the surface waves caused by various shapes of submerged objects in open channel flow will be studied. The relative submergence, Froude number, the approach velocity profile, etc. will be varied. A surface wave characteristic will be studied and related to the drag on the respective objects.
- (5135) LIFT FORCES ON ISOLATED REGULAR OBJECTS ATTACHED TO A BOUNDARY.
- (b) Laboratory project (NSF grant has been applied for).
 (c) Dr. Gordon H. Flammer, Assoc. Prof., Civil and Irrigation Engrg. Dept., Utah State Univ., Logan, Utah 84321.

- (d) Experimental and theoretical research leading to a doctoral dissertation.
 - (e) Lift forces on isolated regular objects attached to a boundary will be studied for the following conditions: (1) A three-dimensional, semi-infinite, flow field where viscous forces and approach velocity profile are important. (2) A three-dimensional, finite, flow field where viscous forces, velocity profile, and relative submergence are important. (3) A three-dimensional, finite, flow field, with free surface effects, where viscous forces, velocity profile, relative submergence and gravity forces are important.
- (5136) VELOCITY AND PRESSURE DISTRIBUTION IN ACCELERATED CURVILINEAR FLOW.
- (b) Laboratory project.
 - (c) Dr. Gordon H. Flammer, Assoc. Prof., Civil and Irrigation Engrg. Dept., Utah State Univ., Logan, Utah 84321.
 - (d) This project is primarily theoretical in nature, however, for verification it uses experimental results by others along with theoretical results obtained from classical hydrodynamics. The research is of a basic nature and is the result of a Doctoral research program.
 - (e) The basic objectives of this study may be summarized as: (1) To derive the basic dynamic equations governing laminar flow for a curvilinear coordinate system. (2) To obtain new equations giving the direction and magnitude of the local velocity vector for curvilinear flow of an ideal fluid. Convergence of the streamlines will be considered in contrast to existing relations. (3) To find a more precise relation between velocity profile and streamline curvature or potential line curvature for potential theory. (4) To find a direct solution for the new relation. This solution will give the magnitude and direction of a velocity vector anywhere in the flow field. (5) To verify this relation analytically and experimentally and to compare its accuracy with previous techniques. (6) To apply the new technique in the determination of the velocity function in any curvilinear flow field with symmetrical boundaries such as convergent, divergent, passages. (7) To find a solution for the problem of laminar flow between two concentric boundaries with no temperature gradient effect.
 - (f) This project will be completed by Jan. 1, 1965.
 - (g) The objectives stated in Item (e) have been realized.
 - (h) A doctoral dissertation is presently being prepared and should be completed by Jan. 1, 1965. It should be published and available sometime during the year 1965.
- (5137) DRAG ON A HEMISPHERE IN A THREE DIMENSIONAL FINITE FLOW FIELD WITH FREE SURFACE EFFECTS.
- (b) Laboratory project (NSF grant has been applied for).
 - (c) Dr. Gordon H. Flammer, Assoc. Prof. of Civil and Irrigation Engr. Dept., Utah State Univ., Logan, Utah 84321.
 - (d) Experimental and theoretical research toward a PhD dissertation. This study is basic in nature.
 - (e) The objectives are to study and compare drag on a hemisphere attached to a boundary for: (1) A three-dimensional, semi-infinite, flow velocity profile are important. (2) A three-dimensional, finite, flow field where viscous forces, velocity profile, and relative submergence are important. (3) A three-dimensional, finite, flow field with free surface effects where viscous forces, velocity profile, relative submergence, and gravity forces are important.
 - (g) Since this program has just begun no results are available at present.
- (5138) STATE WATER PLAN INVESTIGATIONS.
- (b) Utah Water and Power Board.
 - (c) Dr. Jay M. Bagley, Civil Engrg. Dept., Utah State University, Logan, Utah 84321.
 - (d) Field investigation.
 - (e) Water supply and use determinations and projections. Frequency analyses of various kinds of hydrologic data.
 - (g) Hydrologic inventories of major study area of state completed.
- (5139) HYDROLOGY OF THE GREAT SALT LAKE.
- (b) Laboratory project.
 - (c) Dr. Jay M. Bagley, Civil and Irrigation Engineering Dept., Utah State Univ., Logan, Utah 84321.
 - (d) Field investigation, applied research.
 - (e) Attempting to develop an adequate description of the sources, amounts and regimen of water inflow into the lake from precipitation, surface flows, and subsurface flows. This will provide the basis on which to predict the effect of future development so that alternative resource use patterns for the lake and its tributary system can be evaluated.
 - (g) Tributary areas have been mapped and categorized according to water use. Climatological, hydrological, and geo-physical information are being incorporated into water balance relation of Great Salt Lake.
- (5140) ELECTRONIC ANALOG MODEL STUDIES OF RIVER BASINS.
- (b) Soil Conservation Service, U.S.D.A., and Utah Water & Power Board.
 - (c) Dr. Jay M. Bagley, Assoc. Prof., Civil Engineering Dept. and Prof. D. L. Chadwick, Asst. Prof. Electrical Engineering Dept., Utah State Univ., Logan, Utah 84321.
 - (d) Experimental.
 - (e) An electronic analog model of a river basin is being constructed. The basic hydrologic processes of precipitation, snowmelt, surface and subsurface runoff, groundwater storage and movement, evapotranspiration, streamflow, etc. have been modeled electronically. Model will be used to predict performance of various parts of hydrologic system resulting from proposed water management and development changes.
 - (g) Model essentially completed.
- (5440) EVALUATION OF EVAPORATION RETARDANTS FOR AERIAL APPLICATION.
- (b) The Proctor and Gamble Company.
 - (c) Dr. Vaughn E. Hansen, Director, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
 - (d) Applied research and field investigations.
 - (e) Evaluate various chemical compositions and particle size gradations of evaporation retardants to determine their suitability for aerial application techniques. Particular emphasis will be given to the longer chain fatty alcohols, C₂₀ and C₂₂.
- (5441) NEW CONCEPTS OF HYDROLOGIC INSTRUMENTATION.
- (b) Laboratory project.
 - (c) Mr. Joel E. Fletcher, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
 - (d) Experimental and field investigation; applied research and design.
 - (e) The aerial measurement of evaporation, evapotranspiration, and sublimation is being attempted by the application of new electronic, sonic, and optical techniques.
- (5442) EVAPORATION AND CLIMATIC STUDIES.
- (b) Laboratory project.
 - (c) Mr. Joel E. Fletcher, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
 - (d) Experimental; applied research.

- (e) Evaporation from land, snow, and water surfaces constitutes the principal losses of water to the United States. The investigation of factors which affect the quantity, quality, and timing of these losses from a climatic standpoint are being investigated in order to assist in the more precise formulation of plans of water utilization.
- (g) On the basis of dendroclimatic records, it appears that many of Utah's irrigation projects have been designed on the basis of a short, wet cycle.
- (5443) MICROCLIMATIC HYDROLOGY.
- (b) Laboratory project.
- (c) Mr. Joel E. Fletcher, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
- (d) Experimental and field investigation; applied research.
- (e) Methods for evaluating and measuring the microclimatic factors associated with water supply and use are being investigated.
- (5444) DESIGN AND CALIBRATION OF A SUBMERGED RECTANGULAR FLUME.
- (b) D.M.A.D. Irrigation Companies, Delta, Utah.
- (c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
- (d) Design; applied research.
- (e) A rectangular flume was designed to operate under submerged flow conditions throughout the entire range of discharges between 20 and 500 cfs. The flume is to be calibrated in place.
- (g) The flume has been constructed and field calibration data obtained. The data are presently being analyzed.
- (h) Publication will be issued during the early part of 1965.
- (5445) TRAPEZOIDAL MEASURING FLUMES.
- (b) Laboratory project.
- (c) Dr. Calvin G. Clyde, Professor of Civil and Irrigation Engineering, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
- (d) Design; applied research.
- (e) A proposed trapezoidal measuring flume with a design discharge of 300 cfs has been modeled in the laboratory. The purpose of this investigation is to arrive at a proper design and also to determine the feasibility of using this type of flume with both critical depth and submerged flow.
- (g) Testing program has been completed. Results to date look very promising regarding the use of this type of flume for discharge measurement under submerged flow conditions.
- (h) Publication will be issued prior to June 1965.
- (5446) THEORY OF INFILTRATION AND FLUID MOVEMENT IN UNSATURATED POROUS MEDIA.
- (b) Laboratory project.
- (c) Dr. Yu-Si Fok, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
- (d) Theoretical, experimental; basic research, applied research.
- (e) To develop mathematical relationships expressing the phenomena of infiltration. Primary interest is the infiltration of water into the soil. Further development is to extend the developed theory to other fluid and media.
To develop mathematical relationships expressing the fluid movement in unsaturated porous media. Primary interest is the movement of water in unsaturated soil.
To evaluate the validity and applicability of the relationships developed from the mathematical analysis by field and laboratory tests.
- (g) Equations expressing the infiltration rate as a function of the flow time as well as the hydraulic conductivity, the total potential heads, and initial and final moisture content, and the porosity of the soil for different time periods have been developed. Equations expressing the water movement in unsaturated soils as a function of the flow time have been developed.
- (h) "An Infiltration Theory Derived from Potential Gradients," by Yu-Si Fok and Vaughn E. Hansen. (publication pending)
"Theory of One Dimensional Infiltration under a Variable Head," by Yu-Si Fok and Vaughn E. Hansen. (publication pending)
"One Dimension Infiltration into Layered Soil," by Yu-Si Fok and Vaughn E. Hansen. (publication pending)
- (5447) EFFECT OF MINERALIZED SPRINGS ON UTAH'S WATER RESOURCES.
- (b) Utah Water & Power Board.
- (c) Dr. J. M. Bagley, Associate Professor of Civil Engineering, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
- (d) Field investigation, applied research.
- (e) In many areas of Utah, water quality problems are aggravated by contribution from highly mineralized springs which feed into regular water supplies. This investigation is to assess the nature and magnitude of these problems and outline possibilities for management to minimize their effect.
Completed.
- (f) A statewide inventory of mineralized springs has provided information about mineral constituents, quantities of flow, and geographic and geologic characteristics. Interpretation and evaluation of this information has permitted appraisal of current and potential effects of these springs on important water supply sources. Possibilities for control and management are being studied.
- (5448) EFFECT OF VARIOUS IRRIGATION TECHNIQUES ON SOIL AERATION, SOIL STRUCTURE, AND CROP RESPONSE.
- (b) Laboratory project.
- (c) Prof. Jack Keller, Assistant Professor, Dept. of Civil and Irrigation Engineering, Utah State University, Logan, Utah 84321.
- (d) Laboratory experimental project dealing with an applied research problem.
- (e) Laboratory studies utilizing a water applicator capable of uniformly applying water at any rate between .01" and 6.0"/hour to the tops of 15 cm diameter soil columns were conducted. The soil columns were fitted with special soil depth, air permeability, and drainage apparatus. Water application rates of .04, .08, .16, .32, .64, 1.3, 2.6, and 5.2"/hour were applied to samples of a silty clay loam soil having various initial moisture contents and salinity levels. Three salinity levels giving an EC_e of 8, 12, and 16 M MOS were produced by adding calcium chloride to the soil. Various salinity, soil moisture, density, permeability, and drainage measurements were recorded prior to, during, and following the application of a sufficient quantity of water to completely leach the salt from each sample.
- (g) For each soil there is an application rate below which no change in apparent specific gravity or settlement takes place during the initial watering (the critical rate was approximately 0.2 inches per hour for the soils tested.) The percent saturation during watering follows the relationship of: $\%S = CI^n$, where I is the application rate and C and n are constants for a given soil and soil compaction.
Determination of certain new relationships between water application rate, the initial salinity, density, and soil moisture content, and leaching efficiency. The findings of the research to date are useful in irrigation system design and land reclamation

- activities. Relationship between water application and leaching are important for salinity control and drainage investigations.
- (h) "The Effect of Water Application Rate on Soil Structure," by Jack Keller. Paper No. 63-733, printed and presented at the 1963 winter meeting of the American Society of Agricultural Engineers. (Accepted for publication in Agricultural Engineering.)
- "Less Soil Compaction with Low Application Rate Sprinkling," by Jack Keller. Utah Agr. Exp. Sta. Form Paper 399. Presented to the 1964 open technical meeting of The Sprinkler Irrigation Assn. and contained in the printed proceedings, pp. 45-50.
- "Sprinkler Application Rates on Soil Structure," by Jack Keller. Irrigation Engineering and Maintenance, June-July 1964, pp. 17-18, 25.
- (5449) HYDRAULICS AND EFFICIENCY OF IRRIGATION APPLICATION.
- (b) Laboratory project.
- (c) Dr. A. Alvin Bishop, Dept. of Civil and Irrigation Engineering, or Dr. Yu-Si Fok, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
- (d) Theoretical with field investigation; applied research.
- (e) To develop basic mathematical relationships expressing the hydraulics of surface irrigation.
- To evaluate the validity and reliability of the relationships which have been developed from mathematical analysis by field and laboratory tests.
- To develop the nomographs for use with equations developed.
- To develop the relationships for application efficiency and distribution efficiency with regard to the intake rate, advance rate, and the ratio of the required irrigation time to the required water advance time to cover the whole length of a field.
- (g) Equations of the advance of water during irrigation for a furrow or a border in terms of irrigation time, inflow rate, width of the flow channel, slope and roughness of the flow channel and the intake rate have been developed.
- Rational equations for the water surface profile on the soil surface and the water distribution profile in the soil during irrigation have been developed.
- A rational equation for the water distribution profile in the soil after irrigation has been developed.
- Equations for application and distribution efficiencies with regard to the intake rate, the advance rate, and the ratio of the required irrigation time to the required water advance time to cover the whole length of a field have been developed.
- Field test data show good agreement with the equations developed.
- (h) "Analysis of the Advance of Water in Surface Irrigation," by Yu-Si Fok and A. Alvin Bishop. Accepted for publication by Journal of the Irrigation and Drainage Division, American Society of Civil Engineers.
- (5450) ELECTROKINETIC POTENTIAL IN SOIL CAPILLARIES.
- (b) Laboratory project.
- (c) Dr. Calvin G. Clyde, Civil Engineering Department, Utah State University, Logan, Utah 84321.
- (d) Experimental and theoretical; basic research for PhD dissertation.
- (e) To investigate the relationships between the streaming potential developed in a porous medium through which flow is taking place to the soil parameters, the fluid parameters, and the quantity of flow. Necessary equipment and instrumentation are being developed.
- (5451) SEEPAGE FLOW THROUGH DUNES IN ALLUVIAL CHANNELS.
- (b) Laboratory project.
- (c) Dr. Gary Z. Watters, Assistant Professor of Civil Engineering, College of Engineering, Utah State University, Logan, Utah 84321.
- (d) Experimental.
- (e) Experiments are being conducted to determine the permeability of the undisturbed dune structures occurring in alluvial channels. These results will be used to compute seepages through dunes, both in the direction of flow along the channel and vertically downward. This is done to determine the effect of dune movement on the permeability and seepage characteristics of the bed materials.
- (g) Preliminary investigations show measurable differences in permeability in the horizontal and vertical directions. These values in turn differ considerably from the permeability of disturbed samples of bed material.
- (5452) HYDRODYNAMICS OF FREE SURFACE FLOW OVER HYDRAULIC STRUCTURES.
- (b) Laboratory project.
- (c) Dr. Gary Z. Watters, Assistant Professor of Civil Engineering, College of Engineering, Utah State University, Logan, Utah 84321.
- (d) Theoretical and experimental, theoretical and applied.
- (e) Flow configurations over various types of hydraulic structures such as weirs and sills are determined theoretically through the use of complex variables and conformal mapping. The results are to be compared with physical flows produced in the laboratory to establish the usefulness of the theory in describing the actual flow.
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- VIDYA DIVISION, Itek Corp.
- (5199) THE EFFECT OF FLOW SEPARATION FROM THE HULL ON THE STABILITY OF A HIGH SPEED SUBMARINE.
- (b) Office of Naval Research, David Taylor Model Basin (jointly) under the BuShips Fundamental Hydromechanics Program.
- (c) Mr. S. B. Spangler, Vidya Division, 1450 Page Mill Road, Palo Alto, Calif. 94304.
- (d) Theoretical; applied research.
- (e) The lift distribution on the fairwater and fairwater planes at angles of attack and sideslip is characterized by a potential vortex system, whose vortex filaments trail aft over the hull and control surfaces at the stern. A vortex interference force distribution is computed on the hull, stern planes, and rudders. The purpose of the work is to predict theoretically the static stability characteristics of high speed submarines with interference and hull flow separation.
- (g) Results for low angles of attack and sideslip with no hull flow separation indicate that vortex interference effects are appreciable only for the case of high fairwater plane deflection angles at very small hull angles of attack and sideslip and the case of sideslip, where the fairwater becomes loaded.
- (h) "Theoretical Prediction of Vortex Interference Effects on the Static Stability of a High Speed Submarine," S. B. Spangler, and J. A. Burnell. Vidya Rept. No. 157, December 1964.
- (5200) INTERFERENCE BETWEEN A HULL AND A STERN-MOUNTED DUCTED PROPELLER.
- (b) Dept. of the Navy, Bureau of Ships Fundamental Hydrodynamics Research Program.
- (c) Dr. A. R. Kriebel, Staff Engineer, Vidya Division of Itek Corp., 1450 Page Mill Road Palo Alto, Calif. 94304.
- (d) Theoretical investigation; applied research.

- (e) The hydrodynamic interference forces are predicted for an underwater hull with a ducted propeller mounted near the stern. The purpose is to determine the effect of duct shape, size, and location upon the interference forces for a specified hull shape and for steady axially symmetric flow. Existing potential flow theory is used to represent the ducted actuator disk and concentrated singularities are used to represent the hull and its wake.
 - (g) The computed results indicate that certain highly cambered ducts produce no interference drag on the hull and no leading edge suction on the duct even when the duct carries more thrust than the propeller. The effect of the duct boundary layer will be included in future analysis.
 - (h) "Interference Between a Hull and a Stern - Mounted Ducted Propeller," A. R. Kriebel, Vidya Report 161, Sept. 30, 1964.
- (5201) THEORETICAL INVESTIGATION OF DYNAMIC STABILITY DERIVATIVES OF DUCTED PROPELLERS.
- (b) Bureau of Naval Weapons, Dept. of the Navy.
 - (c) Dr. A. R. Kriebel, Staff Engineer, Vidya Div. of Itek Corp., 1450 Page Mill Road, Palo Alto, Calif. 94304.
 - (d) Theoretical investigation; applied research.
 - (e) The force and moment coefficients at angle of attack and their dynamic pitching derivatives are predicted by potential flow analysis for an isolated ducted propeller. A first-order analysis is made of the interference between a pair of ducted propellers in a freestream at angle of attack.
 - (g) Predictions based upon actuator disk representation of the propeller compare favorably with experimental data. The effect of non-uniformity of disk loading upon the predicted results will be investigated. Extension will be made of the analysis of interference which indicates that a large pitching moment is generated on a tandem pair of ducted propellers at angle of attack.
 - (h) "Theoretical Stability Derivatives for a Ducted Propeller," A. R. Kriebel, AIAA Jour. of Aircraft, Vol. 1, No. 4, pp. 203-210, July-Aug. 1964.
- "Theoretical Investigation of Dynamic Stability Derivatives of Ducted Propellers," A. R. Kriebel, Vidya Rept. 112, March 31, 1964.

VIRGINIA POLYTECHNIC INSTITUTE, Dept. of Civil Engineering.

- (5533) USE OF LARGE ROUGHNESS ELEMENTS FOR HYDRAULIC ENERGY DISSIPATION.
- (b) Virginia Council of Highway Investigation and Research and U. S. Bureau of Public Roads.
 - (c) Dr. H. M. Morris, Professor and Head, Dept. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Va. 24061.
 - (d) Analytical and experimental, supplemented by field studies; basic and applied research.
 - (e) Studies are being made to develop general design criteria for flow regimes and energy dissipation in steep channels with large roughness elements. The characteristics of the "tumbling-flow" regime are of special interest. Design applications for chutes, culverts, and other highway drainage structures are in view.
 - (g) First annual progress report has been issued, discussing detailed hydraulics of the tumbling-flow regime in steep, rough channels.
 - (h) "Flow Regimes in a Steep, Rough Channel" by A. N. Al-Khafaji, Dean F. Peterson, and Henry M. Morris, completed and submitted for publication in A.S.C.E. Hydraulics Journal.
- (5534) HYDRAULIC EFFECTS OF BOUNDARY ROUGHNESS.

- (b) Laboratory project.
- (c) Dr. H. M. Morris, Professor and Head, Dept.

- of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Va. 24061.
- (d) Analytical and experimental; basic research, for Ph.D. thesis.
- (e) Systematic studies are being made to delineate the various regimes of turbulent flow in rough pipes in terms of each dimension of the boundary roughness geometry, with the aim of attaining comprehensive quantitative criteria for all regimes.
- (g) Equipment has been constructed and tests are now in progress.

(5535) SEPARATION OF SOLIDS AND LIQUIDS AT FLOW TRANSITION BOUNDARIES.

- (b) National Science Foundation.
- (c) Dr. H. R. Bungay, Prof. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Va. 24061.
- (d) Analytical and experimental; basic research.
- (e) A study was made of the hydraulic characteristics of "clear zones" (zones of clear liquid appearing in suspensions) as produced in vessels filled with a fluid suspension set in motion by stirring action and in flow of the fluid suspensions around obstacles in a channel.
- (f) Investigation has been completed, with recommendations for further studies.
- (g) Characteristics of the clear zones have been studied and a suggested theoretical analysis has been developed, based on the migration of particles across laminar flow streamlines induced by unequal Bernoulli pressures. Applications to sediment transport, flow of blood corpuscles, flow of disease bacteria, and the handling of fibers as in papermaking seem to be indicated.
- (h) "Migration of Particles in Laminar Velocity Fields," by H. R. Bungay and J. M. Wiggert, abstract in Virginia Journal of Science, Vol. 15, September 1964, p. 316.

(5536) HYDRAULIC DISRUPTION AND RE-ENTRAINMENT OF FROTH.

- (b) Division of Water Supply and Pollution Control, U. S. Public Health Service, and Virginia Engineering Experiment Station.
- (c) Dr. W. A. Parsons, Prof. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Va. 24061.
- (d) Analytical and experimental; basic and applied research; Ph.D. Thesis.
- (e) Studies are being made to develop methods to disrupt froth generated in aerobic fermentation processes; hydraulic methods are desired in order to avoid use of bioresistant chemical antifoams which would retard oxygen transfer.
- (g) Experimental measurements have been completed.
- (h) "Hydraulic Disruption and Re-entrainment of Froth," by W. A. Parsons, D. F. Alt, and H. R. Bungay; abstract in Virginia Journal of Science, Vol. 14, September 1963, p. 234.

VIRGINIA POLYTECHNIC INSTITUTE, Dept. of Mechanical Engineering.

(5537) FLUID JET CONTROL.

- (b) National Science Foundation (Grant GK 34).
- (c) Dr. Robert A. Comparin, Assoc. Prof. of Mechanical Engineering, Virginia Polytechnic Inst., Blacksburg, Virginia 24061.
- (d) Analytical and experimental study in part for Master's thesis.
- (e) This project is a study of jet reattachment phenomena at low Reynolds numbers. The study will include both parallel and inclined walls and the effects of aspect ratio, offset, and wall angle.

WASHINGTON STATE UNIVERSITY, The R. L. Albrook

Hydraulic Laboratory.

Inquiries concerning the following projects should be addressed to Dr. E. Roy Tinney, Head, The R. L. Albrook Hydraulic Lab., Div. of Industrial Research, Washington State Univ., Pullman, Washington 99163.

- (1689) STUDY OF FLUID FLOW IN PIPE NETWORKS.
- (b) Personnel responsible for the design and/or operation of water and gas distribution systems.
 - (d) Analyses by analogue and digital computers.
 - (e) Flow distributions have been made with the McIlroy Analyzer for over 50 cities, several gas systems, an air system, a generator cooling system, and several other unique systems. Losses throughout the system are obtained. Engineers use the analogue to design system pumps, tanks, and piping additions or revisions.
- (3848) CALIBRATION OF FLOW METERING FLUMES.
- (b) Agricultural Research Service, Boise, Idaho. Experimental; design, development, master's thesis.
 - (e) Flumes for three specific measuring sites in a watershed of southern Idaho have been developed. Adequate provisions for sediment exclusion are included. Field performance has verified hydraulic model results. Universal application of the design is presently being studied.
 - (g) Preliminary tests indicate that a standard design can be adapted for use at any site as long as topographic and streamflow conditions are within limits thus far investigated. Rating curves can be accurately predicted for the standard design without pre-calibration. Special tests showed that the sediment exclusion features operate so that even large sediment discharge does not affect the discharge rating.
 - (h) "Hydraulic Laboratory Development of Stream Gaging Stations for Reynolds Creek Experimental Watershed," Howard D. Copp, Manuel Th. Arce and E. Roy Tinney. Washington State Inst. of Tech. Research Report 64/9-103, October 1964.
"Effect of Sediment Discharge on the Performance of the V-Type Measuring Flume," Kannson Tsun-Hsien Liu. Thesis prepared as partial fulfillment of requirements for Master of Science Degree in Agricultural Engineering, Univ. of Idaho, June 1964.
- (4721) MODEL CALIBRATION OF ROCK ISLAND SPILLWAY.
- (b) Public Utility District of Grant Co., Washington.
 - (d) Experimental; analytical.
 - (e) A 1:50 scale model of the west section of the Rock Island Dam spillway was constructed. Tests were made to determine the discharge coefficients for each bay as they may be influenced by adjacent and nearby bays, tailwater and apron elevations, and distribution of flow approaching the spillway discharges. Accurate discharge ratings were required in connection with power losses due to tailwater encroachment at Rock Island by the Wanapum pool.
 - (f) Complete.
 - (g) A technique was developed to compute discharge through the western section of the spillway. Effects of upstream topography, tailwater elevation, and spillway gate opening are noteworthy.
 - (h) "Hydraulic Model Studies for the Calibration of the Rock Island Spillway," Claud C. Lomax. Bulletin 282, Washington State Inst. of Tech., Pullman, Washington, June 1964.
- (4724) WELLS COMPREHENSIVE MODEL.
- (b) Bechtel Corporation.
 - (d) Experimental; design.
 - (e) A 1:78 model of the Wells Hydrocombine has been constructed to study potential erosion,
- wave action, passage of migratory fish, spillway capacity, and construction sequences. Since the power house and spillway are combined into one structure, several unique problems in design and operation must be investigated. The model is 44 feet wide and 66 feet long and will pass the equivalent of 1,300,000 cfs.
- (f) Completed.
 - (g) Tests on project layout and operation provided a sound basis for modifying original plans. Additional stream channel protection was required to prevent undue erosion. A rather unusual fish attraction system including several strategically placed, high-velocity jet streams was developed. Downstream geologic formations will permit the spillway flow to scour its own escape channel thereby reducing costly machine excavation.
 - (h) "Wells Hydroelectric Project - Vol. I Comprehensive Model Studies," John S. Gladwell, Howard D. Copp and E. Roy Tinney. Bulletin 289, Washington State Inst. of Tech., Pullman, Washington. In press.
- (5043) THE PLACE OF PUMPED STORAGE IN THE POWER ECONOMY.
- (b) Laboratory project.
 - (d) Theoretical, field investigation.
 - (e) Review of principles and practices of pumped storage projects in Europe and United States.
 - (g) Pumped storage will play an increasing role in large power systems.
 - (h) "Pumped Storage for More Effective Uses of Hydro Resources", R. A. Sutherland. Proc. - 4th Biennial WSU Hydraulics Conference, WSU, November 1963.
- (5519) SOUND SUPPRESSOR-HYDRAULIC MODEL TESTS.
- (b) George C. Marshall Space Flight Center, NASA.
 - (d) Experimental, development.
 - (e) Development of a vane system to create uniform flow around a clover-shaped weir is required. Investigation of initial surge produced by rocket blast and surge suppression is also being undertaken.
- (5520) TRANSIENT SIPHONIC FLOW.
- (b) Laboratory project.
 - (d) Theoretical, experimental, basic research.
 - (e) Mathematical analyses are being developed utilizing Navier-Stokes equations to find the time of establishment of siphonic flow. Experimental tests with fluids of various viscosities are planned.
- (5521) HELLS CANYON HYDROELECTRIC PROJECT.
- (b) Idaho Power Company.
 - (d) Experimental; applied research.
 - (e) Hydraulic model studies on several features of design have been completed. A 1:45 scale flume model of the spillway and low level outlets was employed to investigate energy dissipation characteristics and aperturancex. A 1:60 scale comprehensive model was utilized to study downstream erosion patterns, bank wash, wave generation, fish transportation facilities and diversion schemes during construction.
 - (g) Special nappe deflector application provided adequate energy dissipation at reduced construction costs.
 - (h) "Hydraulic Model Studies of the Hells Canyon Hydroelectric Project," R. A. Sutherland and E. Roy Tinney. Bulletin 284, Washington State Inst. of Tech., Pullman, Washington, June 1964.
- (5522) FLOW AROUND SHARP BENDS.
- (b) Laboratory project.
 - (d) Theoretical, experimental, applied research.
 - (e) Project is being conducted to determine the optimum geometry of channel bends to minimize flow losses. Hydrodynamic theory is being

- developed to consider flow near the inside curve.
- (5523) MECHANISMS OF MASS DISPERSION AND ENERGY DISSIPATION IN FREE LAMINAR AND TURBULENT LIQUID SHEETS.
- (b) Laboratory project.
 - (d) Theoretical, experimental, basic research.
 - (e) Two laminar or turbulent jets, colliding from opposite directions, form a thin expanding sheet or water-bell. G. I. Taylor's equation for the shape of a water-bell has been extended to include gravitational force. Possible mechanisms for mass dispersion and energy dissipation in these sheets are being investigated.
- (5524) HYDRAULIC MODEL STUDIES FOR THE ROCK ISLAND FISH ATTRACTION FACILITIES.
- (b) Public Utility District of Grant County, Washington.
 - (d) Experimental.
 - (e) The purposes of the model study were, (a) to develop a gate opening and closing sequence to facilitate the passage of anadromous fish through the center and right bank fishladders, and (b), to document flow patterns and velocities in the tailrace region under encroachment conditions caused by the construction of Wanapum Dam.
 - (f) Complete except for report.
 - (g) The gate operating sequence appears to be adequate under field conditions.
 - (h) Report in preparation.
- (5525) TRANSIENT EFFECTS IN TIEN'S NUCLEATE BOILING HEAT TRANSFER MODEL.
- (b) State of Washington and Mechanical Engineering Department.
 - (d) Basic research.
 - (e) Attempt is made to account for transient heat convection effects near active nucleation sites in Tien's steady convection model for nucleate boiling.
 - (f) Complete up to presentation at ASME Winter Annual Meeting.
 - (g) Inclusion of transient effects, modifies the form of the resulting Yamagata equation.
 - (h) "Transient Effects in Tien's Nucleate Boiling Heat Transfer Model," R. F. Boehm and John H. Lienhard, ASME Paper 64-H-134.
- (5526) ON CORRELATING THE PEAK AND MINIMUM BOILING HEAT FLUXES, PRESSURE AND HEATER CONFIGURATION.
- (b) State of Washington and Mechanical Engineering Department.
 - (d) Basic research.
 - (e) The peak (or burnout) nucleate boiling heat flux and the minimum film boiling heat flux are shown to be correlatable with geometric scale and pressure.
 - (f) Complete, up to presentation at Annual AIChE-ASME Heat Transfer Meeting (Los Angeles, Aug. 1965).
 - (g) About 350 original data and conclusions about the separability of the pressure and geometry effects.
 - (h) "On Correlating the Peak and Minimum Boiling Heat Fluxes Pressure and Heater Configuration," John H. Lienhard and K. Watanabe. ASME Paper No. 64-H-165.
- (5527) A STUDY OF CAVITATION AND FLASHING IN FREE AND SUBMERGED JETS.
- (b) State of Washington.
 - (d) Basic research.
 - (e) Cavitation numbers have been obtained for various submerged water jets over large temperature ranges. Flashing behavior of free water jets has been observed and correlated. Free jets have been found to sustain up to 100°F. superheat.
 - (f) Final write-up.
 - (h) Discussion of paper 64 by Starkman, Schrock, et al, Jour. Basic Engr., June 1964.
- (5528) SEISMIC INVESTIGATIONS IN THE REYNOLDS CREEK EXPERIMENTAL WATERSHED.
- (b) U. S. Dept. of Agriculture, Agricultural Research Service.
 - (d) Applied research in a field investigation.
 - (e) Refraction seismic studies are being directed toward the solution of complex structural and stratigraphic problems which control the movement of ground waters in the watershed. Much valuable information on the physical characteristics of the numerous rock units is being derived.
 - (f) Project is being conducted as funds permit. Further work is anticipated.
 - (g) Reports covering studies during the past two summers have been completed. Seismic techniques appear to provide much information not otherwise available.
 - (h) "Preliminary Reynolds Creek Seismic Studies," R. E. Cavin, Washington State Inst. of Tech., Research Report No. 63/9-152, 1963. "Seismic Investigations in the Reynolds Creek Experimental Watershed," James W. Crosby, III, Washington State Inst. of Tech., Research Report 64/9-111, 1964.
- (5529) EVALUATION OF THE PULLMAN-MOSCOW GROUND WATER SITUATION BY TRITIUM AND CARBON-14 DATING TECHNIQUES.
- (b) City of Pullman, City of Moscow, Washington Department of Conservation, Washington State University, University of Idaho.
 - (d) A field and laboratory study involving both applied and basic research.
 - (e) Ground-water samples are being collected from specific aquifers throughout the Pullman-Moscow basin. These samples are being analyzed for their tritium and carbon-14 contents in the attempt to determine recharge conditions and localities of natural recharge.
 - (f) Project is continuing.
 - (g) Current information indicates that ground waters have been in storage for thousands of years and that recharge is minor.
 - (h) "A Comprehensive Approach to a Local Ground Water Problem," J. W. Crosby III. Proceedings N.S.F. Water Resources Conference, New Mexico State Univ., 1964.
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- UNIVERSITY OF WASHINGTON, Fisheries Research Inst.
- (3535) EFFECTS OF LOGGING ON PRODUCTIVITY OF PINK SALMON STREAMS IN ALASKA.
- (b) Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, Juneau, Alaska, is contracting agency. Co-operating agencies are Northern Forest Experiment Station, U. S. Forest Service, Juneau, Alaska, and Alaska Department of Fish and Game, Juneau, Alaska.
 - (c) Prof. Donald E. Bevan, Associate Professor, Fisheries Research Institute, University of Washington, Seattle, Wash. 98105.
 - (d) Experimental, theoretical, and field investigation; basic and applied research, including master's and doctoral thesis research.
 - (e) To identify environmental factors causing mortality of pink salmon embryos; (2) to gain a more complete understanding of inter-relationships among spawning behavior, physical and biological attributes of the stream and spawning bed, and mortality of embryos; (3) to determine how the quality of the spawning bed environment as it pertains to growth, development, and mortality of embryos is affected by logging; and (4) to determine criteria for increasing production of fry, the improvement of natural spawning areas and construction of artificial spawning areas. Included among active routine studies are hydrological conditions, intragravel water quality, gravel composition, streambed freezing, gravel shift, spawner counts, and embryo

- mortality. Gravel sampling equipment and techniques are being tested and improved upon.
- (g) Methods have been developed for routine field measurements of intra-gravel water quality, gravel composition, and mortality of salmon embryos. The major causes of egg and larval mortality have been found to be: (1) redd superimposition, (2) streambed freezing, (3) inadequate supplies of good quality intragravel water, and (4) gravel shift due to floods. Stream environmental changes due to logging have been found to be mainly the result of the addition of logging debris or increased sedimentation. A theoretical model of factors controlling interchange between stream and intragravel water has been proposed and tested qualitatively.
- (h) A limited number of reprints of the following publications are available from Fisheries Research Institute, Univ. of Washington, Seattle, Washington 98105. The theses are available on Interlibrary Loan from the University of Washington Library, Seattle.
- "Variations in the Dissolved Oxygen Content of Intragravel Water in Four Spawning Streams of Southeastern Alaska," by William J. McNeill. U.S. Fish and Wildlife Service Special Scientific Report--Fisheries No. 402, 15 p., 1962.
- "Interchange of Stream and Intragravel Water in a Salmon Spawning Riffle," by Walter G. Vaux. U.S. Fish and Wildlife Service Special Scientific Report--Fisheries No. 405, 11 p., 1962.
- "Waterflow Through a Salmon Spawning Riffle in Southeastern Alaska," by William L. Sheridan. U.S. Fish and Wildlife Service Special Scientific Report--Fisheries No. 407, 20 p., 1962.
- "Variability in Pink Salmon Escapements Estimated From Surveys on Foot," by William L. Sheridan. U.S. Fish and Wildlife Service Special Scientific Report--Fisheries No. 408, 7 p., 1962.
- "Relation of Stream Temperatures to Timing of Pink Salmon Escapements in Southeast Alaska," by William L. Sheridan. H. R. MacMillan Lectures in Fisheries, 1960. University of British Columbia, Vancouver, Canada, p. 87-102, 1962.
- "An Experiment to Improve an Alaskan Salmon Spawning Area," by Donald E. Bevan. Science in Alaska, 1962, Proceedings of the Thirteenth Alaskan Science Conference, Juneau, Alaska, August 22-26, 1962. 1963. (Abstract only.)
- "Success of Pink Salmon Spawning Relative to Size of Spawning Bed Materials," by William J. McNeill and Warren H. Ahnell. U.S. Fish and Wildlife Service Special Scientific Report--Fisheries No. 469, 15 p., 1964.
- "New Methods for Sampling Bottom Fauna and Periphyton in Salmon Spawning Gravels," by Warren H. Ahnell. M.S. Thesis, Univ. of Washington, Seattle, 83 p., 1961.
- "Fluid Flow in the Open-Surfaced Porous Bed," by Walter G. Vaux. M.S. Thesis, Univ. of Minnesota, Minneapolis, 85 p., plus appendices, 1961.
- "Mortality of Pink and Chum Salmon Eggs and Larvae in Southeast Alaska Streams," by William J. McNeill. Ph.D. Thesis, Univ. of Washington, Seattle, 271 p., 1962.
- (4247) IMPROVEMENT OF SALMON SPAWNING AREAS IN INDIAN CREEK, ALASKA.
- (b) U.S. Forest Service, Juneau, Alaska, Bureau of Commercial Fisheries, Alaska, and Department of Fish and Game, Juneau, Alaska.
- (c) Prof. Donald E. Bevan, Associate Professor, Fisheries Research Institute, University of Washington, Seattle, Wash. 98105.
- (d) Experimental, theoretical, and field investigation basic and applied research, including thesis research.
- (e) Artificial spawning areas have been constructed on Indian Creek on Prince of Wales Island within the Tongass National Forest, Alaska. The project is to test the general hydraulic considerations associated with the design of improved pink salmon spawning areas in natural streams. Objectives of the research program are to test the design of artificial improvements to salmon spawning grounds. The problem is to determine if we can provide, at reasonable cost, small areas of stable permeable gravel in which low water flow of stream will be concentrated. The evaluation of artificially constructed channels will provide information of the detailed requirements of spawning fish as well as the requirements of eggs and larvae. Further information will be obtained on movement of bed material as no stream flow regulation is provided.
- (g) Flooding in the fall of 1961 and the winter of 1962-63 caused considerable gravel shift and streambed erosion in the artificial spawning channel, altering the original design and necessitating reconstruction. The 1961 floods apparently caused no significant embryo mortality, while the 1962-63 floods did. For artificial spawning channels to be successfully maintained at reasonable cost in most southeastern Alaska streams, flow control must be provided.
- (4730) DETERMINING CHANGES IN SIZE COMPOSITION IN STREAMBED MATERIAL IN LOGGED WATERSHEDS.
- (b) Institute of Forest Products, Univ. of Washington.
- (c) Prof. Donald E. Bevan, Associate Professor, Fisheries Research Institute, Univ. of Wash., Seattle, Wash. 98105.
- (d) Experimental, theoretical and field investigation; applied research for M.S. thesis.
- (e) The research is to evaluate ecological changes in salmon streams caused by deforestation. Soil erosion, subsequent logging operations in a watershed, may cause large quantities of fine particles to be deposited in the beds of the streams adjacent to logging areas. The presence of fine materials reduces the permeability of the stream and gravel thereby reducing the rates of waterflow in the streambed and the rate of exchange of intergravel water. The rate of exchange between the intergravel and stream water limits the quality of the intergravel environment of the habitat for salmon eggs and larvae. The results of the proposed investigation will assist in determining if logging will affect salmon production. The objectives of the study are: (1) To evaluate the present gravel sampling procedures and index of streambed quality for salmon; (2) to determine the physical factors controlling the size of the particles within the stream bed; (3) determine if streambed composition can be used to measure effects of logging on salmon.
- (g) Data currently being analyzed.
- (5019) THE ECOLOGY OF BOISE CREEK.
- (b) The Weyerhaeuser Company.
- (c) Prof. Donald E. Bevan, Assoc. Prof., Fisheries Research Institute, Univ. of Washington, Seattle, Washington 98105.
- (d) Experimental, theoretical, and field investigation; basic and applied research, including master's thesis research.
- (e) Sewage effluents from industrial, agricultural and domestic sources have been regularly discharged into Boise Creek for many years. It is the purpose of the study to gather ecological, hydrographic, and chemical data in several strata of stream use to determine the suitability of Boise Creek as a spawning and rearing stream for salmonid fishes.
- (g) Data currently being analyzed.
- (5034) EVALUATION OF STREAM CARRYING CAPACITY OF FINE MATERIALS AS RELATED TO GRAVEL PERMEABILITY.

- (b) Institute of Forest Products.
- (c) Prof. Donald E. Bevan, Associate Professor, Fisheries Research Institute, Univ. of Wash., Seattle, Washington 98105.
- (d) Experimental, theoretical, and field investigation; applied research for M.S. thesis.
- (e) This research is to aid in evaluating the changes in salmon streams caused by logging. Soil erosion caused by logging at times increases the amount of fine particles within the flowing stream. Depending upon the hydraulic conditions within the stream and the water turbidity, the streambed permeability will be lowered. Reduced permeability lowers the water interchange between the gravel and bed. The amount of intra-gravel flow is vital to the survival of salmon eggs and larvae. The investigation will attempt to define the hydraulic conditions and define concentration for a particular permeability. The objectives of the study are: (1) Determine experimentally the amount of deposition of fines in gravel; (2) for given hydraulic conditions, streambed composition and turbidity a theoretical prediction of the streambed permeability; (3) measurement of stream hydraulic conditions, turbidity, bottom composition and permeability; and (4) analysis of data and previous permeability data available to determine limitations of turbidity on salmon stream.

UNIVERSITY OF WASHINGTON, Charles W. Harris
Hydraulics Laboratory.

- (4725) SALT WATER ENTRAINMENT FOR DILUTION IN SEWER OUTFALLS.
 - (b) U. S. Department of Health, Education, and Welfare-Public Health Service.
 - (c) Prof. R. E. Nece, Dept. of Civil Engineering, University of Washington, Seattle, Wash., 98105.
 - (d) Experimental; basic and applied research.
 - (e) The mechanism of the entrainment of a fluid from an infinite still reservoir through discrete ports into a conduit flowing full is to be studied experimentally and analytically.
 - (g) Data have been obtained for a range of single circular ports of varying sizes for zero and small density differentials between conduit and entrained fluids; some multi-port data have been obtained for the zero density difference case.
 - (h) Two M. S. Thesis completed (available on loan).
- (4726) A STUDY OF VELOCITY BARRIER DEVICE FOR DOWNSTREAM MIGRANT BYPASS.
 - (b) Columbia Fisheries Program Office, U. S. Bureau of Commercial Fisheries, Portland, Oregon.
 - (c) Prof. H. S. Strausser, 317 Hydraulics Lab., University of Washington, Seattle, Wash., 98105.
 - (d) Experimental investigation; developmental research.
 - (e) The problem requires a structure which will guide downstream migrant fish into a collection facility with a minimum obstruction to flow. The methods under study utilize velocity changes which would attract or repel the fish, thereby steering them into a desired location.
 - (f) Discontinued.
 - (g) Results inconclusive.
- (5113) MODEL STUDY OF THE MOSSYROCK DAM AND SPILLWAY.
 - (b) Harza Engineering Company and the City of Tacoma, Major Projects Division.
 - (c) Professors E. P. Richey and H. S. Strausser, Univ. of Washington, Seattle, Wash. 98105.

- (d) Experimental and applied research.
- (e) The study will be concerned especially with erosion resulting from spillway flows as well as the usual problems of a dam and spillway model.
- (f) Completed.
- (h) Report submitted to sponsoring agency.

(5530) A STUDY OF INFILTRATION BENEATH A FOREST FLOOR.

- (b) Office of Engineering Research; Univ. of Washington.
- (c) Prof. Thomas H. Campbell, Dept. of Civil Engineering, Univ. of Washington, Seattle, Washington 98105.
- (d) Field laboratory investigation; theoretical.
- (e) Instrumentation permits accurate, continuous recording of flow of moisture past points in unsaturated soil. Flow data obtained at various plan locations and at various depths are recorded on tape, transformed by computer to hydrograph display. This information will be correlated with an analytical model.

(5531) HYDRAULICS OF FLOW OVER AN INCLINED, POROUS PLATE.

- (b) Laboratory project.
- (c) Prof. E. P. Richey, Dept. of Civil Engrg., Univ. of Washington, Seattle, Wash. 98105.
- (d) Experimental; basic research.
- (e) Flow distribution, surface profile determined as depending upon bed slope and porosity.

(5532) BED SHEAR AS AN INDEX OF HYDRAULIC JUMP EFFICACY.

- (b) Laboratory project.
- (c) Prof. R. E. Nece, Dept. of Civil Engrg., Univ. of Washington, Seattle, Wash. 98105.
- (d) Experimental; basic research.
- (e) Boundary shear stresses are used as an index of determining energy dissipation efficiencies of hydraulic jump in rectangular stilling basins; the procedure provides another description of the effective length of the jump as that within which the bed shear is reduced to safe limits.
- (g) Data have been obtained for jumps on a horizontal floor and for jumps with approach slopes of 1 in 5, 1 in 3, and 1 in 1.5.
- (h) One M.S. thesis completed (available on loan).

WEBB INSTITUTE OF NAVAL ARCHITECTURE.

(5202) DETERMINATION OF SHIP WAVE RESISTANCE.

- (b) David Taylor Model Basin, Bureau of Ships, Dept. of the Navy.
- (c) Dr. Lawrence W. Ward, Prof. of Engineering, Webb Institute of Naval Architecture, Glen Cove, Long Island, New York 11542.
- (d) Experimental and theoretical; basic research.
- (e) Investigation of means for direct experimental determination of ship wave resistance from measurements of the wave pattern during a model test. Purpose includes improvement in scaling model test results to full size as well as basic understanding of nature of ship resistance.
- (g) Method utilizing forces exerted by the wave pattern on a long vertical cylinder has been developed and tests run. Results are encouraging and in agreement with other investigators. Experimental wave resistance when added to estimated skin friction is less than measured total resistance. New method utilizing wave slope records being investigated.
- (h) Report in preparation.

(5203) ASSESSMENT OF SEAKEEPING CHARACTERISTICS OF SHIPS.

- (b) Society of Naval Architects & Marine Engineers, Panel H-7 of Hydrodynamic Committee.
- (c) Prof. Edward V. Lewis, Research Prof. of Naval Architecture, Webb Institute of Naval Architecture, Glen Cove, L. I., N. Y. 11542.
- (d) Theoretical application of available experimental results and confirmation by model tests; applied research.
- (e) Application of available knowledge of ship model behavior in regular waves to the prediction of trends of ship performance in realistic irregular wave patterns. Experimental confirmation by means of model tests in waves. Purpose is to provide the ship designer with guidance in the selection of hull characteristics.
- (f) Theoretical work is completed.
- (g) The advantage of a high length/draft ratio in permitting higher speeds before shipping water forward is clearly shown. A corresponding disadvantage in terms of likelihood of slamming is found, requiring a balance to be made in selecting optimum ship characteristics.
- (h) "Applying Results of Seakeeping Research," E. V. Lewis, Fifth Symposium on Naval Hydrodynamics, Bergen, Norway, September, 1964. (To be published by Office of Naval Research, Washington 25, D.C.)
- (d) Madison, Wisconsin 53706.
- (d) Theoretical and experimental; applied research and design for B.S., M.S. and Ph.D. theses.
- (e) Energy loss measurements in straight pipes and fittings have been completed on sizes 1/4 inch to 2 inches. Pressure range 0-2500 psi, temperature range 60 to 120 degrees F. Reynolds number range 50 to 150,000.
- (f) Completed.
- (g) If viscosity, density, and temperature relations are known, the standard pipe friction theory applies at high pressures. The fitting loss constants for laminar flow are about 3 times those for turbulent flow when $N_R = 2000$. The loss gradually reduces to zero at $N_R = 150$.
- (h) "Effect of Pressure and Temperature on the Viscosity of Petroleum Oils", V. N. Gunaji, and J. R. Villemonte, Proceedings of the 3rd Midwestern Conference on Fluid Mechanics, Univ. of Minnesota, 1953.
"Pipe Friction Loss at High Pressures", J. G. Slater, J. R. Villemonte, H. J. Day, Proceedings of ASCE Hydraulics Division, February, 1957.

(1181) VORTEX FLOW FROM HORIZONTAL THIN-PLATE ORIFICES.

THE WESTERN COMPANY, Research Division.

(5291) EFFECT OF MOLECULAR SIZE AND SHAPE ON DRAG REDUCTION.

- (b) David Taylor Model Basin, Fundamental Hydromechanics Research Program.
- (c) Dr. H. R. Crawford, The Research Div. of The Western Company of North America, 1171 Empire Central, Dallas, Texas 75247.
- (d) Experimental; basic research.
- (e) The laminar and turbulent friction loss of dilute water solutions of various polymers are being determined in order to relate the friction reduction obtained with the molecular dimensions of the polymer.

(5292) OPTIMUM CONCENTRATION OF FRICTION REDUCING ADDITIVES FOR PIPE FLOW.

- (b) Laboratory project.
- (c) Dr. H. R. Crawford, The Research Div. of The Western Company of North America, 1171 Empire Central, Dallas, Texas 75247.
- (d) Experimental; applied research.
- (e) Turbulent friction loss data were taken and in laboratory size tubing with water containing a friction reducing additive. These data were fitted to an empirical equation which was used to obtain an optimum additive concentration.
- (f) Completed.
- (g) Field results verified the empirical correlation. This empirical equation indicates that the turbulent friction loss data cannot be correlated by the use of a Reynolds number only.
- (h) "A Method to Minimize Cost of Pumping Fluids Containing Friction Reducing Additives," G. T. Pruitt, C. M. Simmons, G. H. Neill, and H. R. Crawford. Prepared for Society of Petroleum Engineers Meeting, Houston, October 1964.

UNIVERSITY OF WISCONSIN, Hydraulics and Sanitary Laboratories.

(956) ENERGY LOSS IN LIQUID FLOW IN PIPES AND FITTINGS UNDER HIGH PRESSURE.

- (b) Laboratory project in cooperation with the Ladish Company, Cudahy, Wisconsin, and the Wisconsin Alumni Research Foundation.
- (c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin,

- (b) Laboratory project.
- (c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
- (d) Theoretical and experimental; basic research for M.S. and Ph.D. theses.
- (e) The effects of vorticity on orifice discharge are being studied over a wide range of vorticity, head, orifice size, and fluid viscosity.
- (g) A new parameter, the vortex number, was developed as the ratio of inertial and centrifugal forces. A general correlation procedure was also developed for estimating discharge rates through orifices with varying degrees of vorticity.

(3539) DISTURBED LAMINAR AND TURBULENT FLOW.

- (b) Wisconsin Alumni Research Foundation.
- (c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
- (d) Theoretical and experimental; basic research for M.S. and Ph.D. theses.
- (e) The equation of motion has been applied to several situations of disturbed laminar and turbulent flow and compared with experimental results. Flows are disturbed using orifices and screens. Turbulence is measured by a newly developed magnetohydrodynamic probe in conjunction with analog and digital computers to give the turbulence energy spectra.
- (g) New equations have been developed for estimating losses due to combined and divided flow as well as losses due to other disturbances. Turbulence energy spectra have been developed for a wide variety of boundary configurations. The new probe permits the observation of the distribution of turbulent energy across the section of flow.
- (h) "Disturbed Turbulent Flow", H. J. Day, Ph.D. Thesis, 1963, Univ. of Wisconsin, Paper for publication is in preparation.

(3540) MODEL STUDIES OF PUMP INLET STRUCTURES.

- (b) Wisconsin Alumni Research Foundation in cooperation with the Government of West Bengal, India.
- (c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, University of Wisconsin, Madison, Wis. 53706.
- (d) Experimental; design for M.S. thesis.
- (e) A 1/16-scale model of the inlet structure for one of four axial flow pumps at the Uttarbhag Pumping Station (Sonarpur, India) has been made. Studies of inlet flow

- patterns and pressure coefficients for a wide variety of flow situations are being made for the purpose of reducing the cavitation threshold.
- (f) Completed.
 - (g) Pressure coefficients were computed at 37 points on the model over a wide range of flows.
 - (h) "Model Study of Pump Inlet Conditions at Uttarbhag, India", C. K. Sarkar, J. R. Villemonte, and S. Kar, Indian Journal of Power and River Valley Development, Univ. of Wisconsin Engineering Experiment Station Reprint No. 666.
- (3541) HYDRAULIC CHARACTERISTICS OF GRAVITY SEPARATION BASINS.
- (b) National Institutes of Health, Washington, D. C.
 - (c) Dr. J. R. Villemonte and Dr. G. A. Rohlich, Hydraulics and Sanitary Laboratories, Madison, Wisconsin 53706.
 - (d) Experimental; basic research and design for M.S. and Ph.D. theses.
 - (e) Hydraulic characteristics of two model circular basins and one model rectangular basin are being studied using a wide range of flow and types of inlet and outlet design, using the fluorescent tracer technique and the automatic recording of dimensionless dispersion curves. Field tests on actual basins are also being undertaken where dispersion curves and removal efficiencies are being observed simultaneously, so that correlations can be studied. The principles of similitude which apply to gravitation separation basins are also being studied in the laboratory and in the field.
 - (g) Hydraulic characteristics have been determined for a wide range of overflow rates and basin types both in the laboratory and field using newly developed criteria. Comparison of actual removal efficiencies and those derived from a new rational approach has been made several laboratory and field basins.
 - (h) In addition to several M.S. and Ph.D. theses, the following papers have been completed: "A Review of Principles Affecting Sedimentation", K. L. Murphy and G. A. Rohlich, Purdue Industrial Waste Conference, 1963. "Hydraulic Characteristics of Gravity Separation Basins", J. R. Villemonte and G. A. Rohlich presented at Annual ASCE Water Resources Conference, Milwaukee, Wisconsin, 1963.
- (3654) REACTION JET INLET FOR OIL-WATER SEPARATORS.
- (b) The American Petroleum Inst.
 - (c) Prof. G. A. Rohlich and Dr. J. R. Villemonte, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisc. 53706.
 - (d) Experimental; basic research and design for master's and doctoral theses.
 - (e) Studies were conducted in a transparent basin 5 feet wide, 10 feet long and 3 feet deep. Investigations were made using various sizes and spacings of a reaction jet at the entrance to the basin to determine the effects of jet inflow on the hydraulic characteristics.
 - (f) Completed.
 - (g) Hydraulic characteristics for rectangular basins with Reaction Jet inlet devices were observed using a wide range of flows.
- (4251) CHANNEL DYNAMICS ABOVE GULLY CONTROL STRUCTURES.
- (b) U.S. Department of Agriculture, Agricultural Research Service.
 - (c) Dr. Arno T. Lenz, Chairman, Dept. of Civil Engineering, University of Wisconsin, 1513 University Avenue, Madison, Wisconsin 53706.
 - (d) Theoretical study and field investigation of basic research in channel dynamics for Ph.D. thesis.
 - (e) Data from field surveys of 44 gully control structures in Southwestern Wisconsin have been analyzed to develop procedures for estimating quantitatively the dynamic changes in channel profiles which occur when a gully control or sediment detention structure is built.
 - (f) Completed.
 - (g) An equation has been developed for the ratio of the average deposition slope to the original channel slope as a function of past and present hydraulic and sediment parameters.
- (4252) FLOW OF A DENSITY STRATIFIED FLUID.
- (b) Laboratory Project.
 - (c) Dr. P. L. Monkmeier, 1261C Engineering Bldg., Univ. of Wisconsin, Madison, Wisc. 53706.
 - (d) Theoretical; basic research.
 - (e) Dynamic characteristics of compressible and incompressible density - stratified fluids, are being investigated. Both steady and unsteady flow problems relating to internal gravity waves are included in the study.
 - (g) Linearized equations for steady, inviscid, compressible flow in atmospheres with various density distribution have been developed and solved for simple boundary configurations.
 - (h) A paper is in preparation.
- (4732) UNIT HYDROGRAPH VARIATION WITH STORM HYDROGRAPH SHAPE.
- (b) Laboratory project.
 - (c) Dr. Arno T. Lenz, Chairman, Dept. of Civil Engineering, 1513 University Avenue, Madison, Wisconsin 53706.
 - (d) Theoretical study and field investigation of the unit hydrograph. Basic research for Ph.D. thesis.
 - (e) A general one-hour dimensionless unit hydrograph derived from 16 Illinois basins was used successfully to derive 92 one-hour unit hydrographs for four midwestern basins of 22 to 77 square miles in area for storms of 1 to 13 hours duration. Computations were made using IBM 1620 and CDC 1604 computers.
 - (f) Ph.D. thesis by Dr. Donald L. Bender completed.
 - (g) Unit hydrographs needed to reproduce single-peak storm hydrographs varied with peak discharge, shape, and volume of the storm hydrographs. Shapes can be described by a dimensionless parameter the ratio of the hydrograph peak to the flow in a rectangular hydrograph of equal runoff volume and unit time base.
 - (h) Paper for A.G.U. in preparation.
- (4733) THE TRANSFORMATION OF RAINFALL ON THREE BASINS IN NORTH CENTRAL WISCONSIN.
- (b) Laboratory project.
 - (c) Dr. A. T. Lenz, Chairman, Dept. of Civil Engineering, University of Wisconsin, 1513 University Avenue, Madison, Wisconsin 53706.
 - (d) Experimental and theoretical with field investigation; basic research for Ph.D. thesis.
 - (e) This study is to determine the relationships existing between rainfall, stream runoff, infiltration, groundwater, and evapotranspiration with respect to three drainage basins in North Central Wisconsin which have both similar and dissimilar soil types and aquifers, based on published data.
 - (h) Ph.D. Thesis by Dr. John F. Orsborn completed. Paper in preparation.
- (4734) FLOW BETWEEN CONCENTRIC ROTATING CYLINDERS.
- (b) Wisconsin Alumni Research Foundation and Fairbanks Morse Co.
 - (c) Dr. P. L. Monkmeier, 1261C Engineering Bldg., Univ. of Wisconsin, Madison, Wisconsin 53706.
 - (d) Theoretical and experimental; basic research for Ph.D. thesis.
 - (e) This study is concerned with the characteristics

of turbulent flow in an annulus, with rotating inner cylinder. Theoretical prediction and experimental confirmation of shearing stresses, torque, pressure gradients, and frictional resistance are being sought.

- (g) A theory has been developed to predict the frictional resistance to turbulent flow in a rotating annulus. Experimental confirmation has been obtained over a limited range of flow conditions.
- (h) Ph.D. Thesis by Dr. L. Gelhar is completed.
- (4735) MODEL STUDY OF A PROPOSED BARRAGE AT MUSCODA, ON THE WISCONSIN RIVER.
 - (b) Muscoda Development Corporation, Muscoda, Wisconsin.
 - (c) Dr. J. R. Villemonte and Dr. P. L. Monkmeier, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
 - (d) Experimental; applied research and design for M.S. thesis.
 - (e) A comprehensive study is under way to determine the possible effects of constructing a barrage, at Muscoda, on the Wisconsin River. The study includes construction of two models to determine scour patterns downstream of the dam, as well as stability of the dam itself. Backwater effects are also being studied.
 - (g) Scour and stability data have been predicted from the results of two model studies. Predictions of upstream backwater levels have been made using the digital computer.
 - (h) Three unpublished theses and project reports have been prepared.
- (4736) UNSTEADY FLOW IN POROUS MEDIA.
 - (b) Laboratory project.
 - (c) Dr. P. L. Monkmeier, 1261C Engineering Bldg., Univ. of Wisconsin, Madison, Wisconsin 53706.
 - (d) Theoretical; basic research for Ph.D. theses.
 - (e) The following problems in unsteady flow through a porous medium are under investigation: use of sound waves to determine permeability; effect of stream bank clogging on unsteady flow of ground water; unconfined, unsteady flow of groundwater toward a surface stream.
- (5011) HYDRAULIC CHARACTERISTICS OF CYLINDRICAL SLOT ORIFICES.
 - (b) W. A. Kates Company.
 - (c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
 - (d) Experimental; design.
 - (e) The effects of viscosity, head, and slot type and shape on the coefficient of discharge are being studied.
- (5597) HYDRAULIC CHARACTERISTICS OF DROP INLETS.
 - (b) U. S. Department of Agriculture, Agricultural Research Service and Laboratory Project.
 - (c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Madison, Wisconsin 53706.
 - (d) Experimental; applied research for M. S. Theses.
 - (e) Model studies will be made of a drop inlet structure located in the head waters of the Kickapoo River Valley, Cashton, Wisconsin. The objective is to determine operating characteristics for several types of crest configurations.
- (5598) CHARACTERISTICS OF GRAVITY WAVES.
 - (b) Laboratory project.
 - (c) Dr. P. L. Monkmeier, 1261C Engineering Building, Univ. of Wisconsin, Madison, Wisconsin 53706.
 - (d) Theoretical; basic research.
 - (e) Higher order theories for finite height

gravity waves are under study.

WOODS HOLE OCEANOGRAPHIC INSTITUTION.

- (4737) EXPERIMENTAL HYDRODYNAMICS OF ROTATING LIQUIDS.
 - (b) Office of Naval Research, Dept. of the Navy.
 - (c) Mr. Alan Ibbetson, WHOI, Woods Hole, Mass.
 - (d) Experimental and theoretical; basic research.
 - (e) Hydrodynamics of rotating liquid systems, including blocking action by topographic features and generation of Rossby waves in an annulus of liquid.
 - (g) Previous results on occurrence of blocking action.
 - (h) Ph.D. Thesis, Nov. 1964, Physics Dept., Univ. of Newcastle on Tyne, England.
- (4738) SYNOPTIC OCEANOGRAPHY - SURFACE EFFECTS.
 - (b) Office of Naval Research, Dept. of the Navy.
 - (c) Mr. Raymond G. Stevens, Woods Hole Oceanographic Institution, Woods Hole, Mass.
 - (d) Experimental, field investigation, basic research, doctoral dissertation.
 - (e) Measurement of the directional spectrum of wind generated gravity waves in the generating area.
 - (g) Directional spectra have been measured in Buzzards Bay, Massachusetts, and Panama City, Florida.

WORCESTER POLYTECHNIC INSTITUTE, Alden Hydraulic Laboratory.

- Inquiries concerning the following projects should be addressed to Professor Leslie J. Hooper, Director, Alden Hydraulic Laboratory, Worcester Polytechnic Institute, Worcester, Mass. 06109.
- (1963) METER CALIBRATIONS.
 - (b) Foxboro, Company, Foxboro, Mass.
 - (d) Experimental, for design.
 - (e) Calibration of various sizes of magnetic flow tubes (1" to 36" diameter) and a variety of nozzle and orifice plate assemblies.
 - (f) Tests in progress.
 - (3859) METER CALIBRATIONS.
 - (b) B-I-F Industries, Providence, R. I.
 - (d) Experimental, for design.
 - (e) Calibration of open flow nozzles and flow tubes up to 48" in diameter. Tests performed in standard test loop and also in mock-up of particular field installations.
 - (f) Tests in progress.
 - (4255) METER CALIBRATIONS.
 - (b) Penn Meter Company, Philadelphia, Pa.
 - (d) Experimental; for design.
 - (e) Calibration of open flow nozzles and flow tubes from 2" to 48" in diameter in the standard test loop. In addition, tests have been performed to determine operating characteristics in a variety of field installation mock-up include a number of pipe surface finishes.
 - (f) Tests in progress.
 - (4740) CHONG PYONG HYDROELECTRIC PROJECT.
 - (b) Stone and Webster Engineering Corp., Boston, Mass.
 - (d) Experimental, for design.
 - (e) A 1/75 scale model of a reach of the North Han River in the Republic of Korea was constructed for the Korea Electric Company. The model included the spillway and powerhouse as well as river topography up and downstream of the development. Studies

- were made of a number of changes designed to improve spillway and powerhouse operation. In addition a number of schemes for the different river diversions and construction planning were studied.
- (f) Experimental work completed.
 - (h) Report in preparation.
- (4741) CORNWALL PUMPED STORAGE DEVELOPMENT.
- (b) Uhl, Hall and Rich, Boston, Mass.
 - (d) Experimental, for design.
 - (e) A 1/80 scale model of the intake at the upper reservoir was constructed including local topography at the intake. The studies involved the flow patterns and possible surface disturbances in the reservoir and also the flow in the first few diameters of the vertical shaft of the intake.
 - (f) Tests completed.
 - (h) Report in preparation.
- (4746) METER CALIBRATIONS.
- (b) Hagan Chemicals and Controls, Inc., Pittsburgh, Penn.
 - (d) Experimental, for design.
 - (e) Calibration of a variety of sizes and designs of flow nozzles and flow nozzle assemblies.
 - (f) Tests in progress.
- (5020) CARDINAL STEAM PLANT.
- (b) American Electric Power Service Corp., New York, N. Y.
 - (d) Experimental, for design.
 - (e) A 1/120 by 1/40 distorted scale model of a section of the Ohio River upstream and downstream from the Cardinal Plant of the Ohio Power Co. The plant inlets and outlets for condenser cooling water were installed for both the present unit and three future units. The studies were performed on the hot water flow patterns in order to insure a minimum of hot water from either the old or the new units re-entering the cooling water system. In addition bed load movement of the river and barge handling techniques were studied over a range of river stages.
 - (f) Experimental work completed.
 - (h) Report in preparation.
- (5021) MUDDY RUN PUMPED STORAGE DEVELOPMENT.
- (b) Philadelphia Electric Co., Philadelphia, Penn.
 - (d) Experimental, for design.
 - (e) A 1/35.3 scale model of the intake structure, the immediate topography in the reservoir and a section of the vertical tunnel below the intake were modeled to study the flow characteristics and evaluate the losses in both the pumping and generating cycles.
 - (f) Work completed.
- (5022) DYNAMIC EFFECTS IN FLOW METER COEFFICIENT PREDICTION.
- (b) Laboratory project.
 - (d) Experimental, for M.S. thesis.
 - (e) A number of differential producer type flow meters are being studied under different Reynolds Number levels with the same volume flow rate. It is planned to evaluate the dynamic effects on the discharge coefficient.
 - (f) Tests in progress.
- (5023) VELOCITY DISTRIBUTION INFLUENCE ON BEND LOSSES.
- (b) Laboratory project.
 - (d) Experimental for M.S. thesis.
 - (e) An experimental and theoretical study of the variation in energy loss in a 90° pipe bend was carried out and evaluation of the loss set up in terms of the upstream velocity distribution.
 - (f) Work completed.
- (5024) CORNWALL PUMPED STORAGE DEVELOPMENT.
- (b) Uhl, Hall and Rich, Boston, Mass.
 - (d) Experimental, for design.
 - (e) A 1/56 scale model of the manifold and penstock sections was constructed of plexiglass and PVC pipe in the appropriate diameters. The sections varied in diameter (full scale) from 40' for the manifold to 10' for the penstocks at the powerhouse. Measurements of pressure head at each change in section and alignment were made to evaluate the loss coefficients in both the generating and pumping situations.
 - (f) Tests completed.
 - (h) Report in preparation.
- (5268) LITTLE GYPSY STEAM POWER PLANT.
- (b) Ebasco Services, Inc., New York.
 - (d) Experimental, for design.
 - (e) A 1/12 scale model of the condenser cooling water intake of the plant of the Louisiana Power Co., including the sump and vertical pump bell mouth was constructed. The studies included various modifications to insure a uniform velocity distribution at the pump intake for the required flows.
 - (f) Tests completed.
 - (h) Report in preparation.
- (5269) CABIN CREEK PUMPED STORAGE DEVELOPMENT.
- (b) Stone and Webster Engineering Corp., Boston, Mass.
 - (d) Experimental, for design.
 - (e) A 1/100 scale model of the upper reservoir of the development of the Public Service Corp. of Colorado was constructed. The model included the reservoir, upper face of the dam and the water intake to the tunnel. The studies involved the flow patterns in the reservoir for various phases of operation including both pumping and generating. A qualitative study of ice flows in the reservoir under the influence of wind was conducted. Treatment of intake location and flow at the intake was evaluated.
 - (f) Test completed.
 - (h) Report in preparation.
- (5270) KASTRAKI HYDROELECTRIC DEVELOPMENT.
- (b) Ebasco Services Inc., New York.
 - (d) Experimental, for design.
 - (e) A 1/100 scale model of the Kastraki development of the Public Power Corp. on the Acheloos River was constructed. The model included a section of the reservoir, the gravity dam, spillway, powerhouse and river bed downstream including the confluence with the Zervas Torrent. The studies include the approach conditions to the side spillway, the supercritical flow in the spillway chute and the conditions in the tailrace area.
 - (f) Tests in progress.
- (5271) CAMPBELL STEAM POWER PLANT.
- (b) Commonwealth Associated Inc., Jackson, Michigan.
 - (d) Experimental, for design.
 - (e) A 1/10 scale model of the intake at the Campbell Plant of the Consumers Power Co. on Lake Michigan was constructed. The local lake section was duplicated in a steel head box and the intake structure was mounted outside to allow viewing of flow patterns through the transparent wall. Studies were aimed at reducing the head loss and disturbed flow in the screenhouse and gate structure.
 - (f) Tests in progress.
- (5272) INDIAN POINT STEAM PLANT.
- (b) Consolidated Edison Co., New York.
 - (d) Experimental, for design.
 - (e) A 1/60 horizontal by 1/40 vertical scale model was constructed of the Indian Point

Atomic Power Plant on the Hudson River. A section of the river either side of the intake and including the intake and its allied docking facilities was modeled. The capability to model the hot condenser effluent was incorporated to facilitate the study of recirculation, mixing and allied density current effects.

(f) Tests in progress.

(5273) CICEROZ HYDROELECTRIC DEVELOPMENT.

- (b) Ebasco Services Inc., New York.
- (d) Experimental, for design.
- (e) The 1/70 scale model was constructed of the Ciceroz development of the Electric Power Generating Co. of Turkey. The model included the stream above and below the site, the arch dam, spillway and the powerhouse and allied water passages. The studies were involved with the approach flow to the spillway and powerhouse intake and the flow results in the tailrace for a variety of flow conditions. Penstocks were fabricated of clear plastic to allow observation of flow in various sections.

(f) Tests completed.

(h) Report in preparation.

(5274) KEBAN HYDROELECTRIC DEVELOPMENT.

- (b) Ebasco Services Inc., New York.
- (d) Experimental, for design.
- (e) A 1/100 scale model of the project on the Euphrates River was constructed for the Electric Power Generating Co. in Turkey. Included in the model was the river above the dam, the dam, water intakes, spillway, fuse plug, penstocks, spillway chute, powerhouse and a section of river downstream including the tailrace. The studies involved intake operation, spillway and gates, fuse plug performance, spillway chute and wall design and tailrace flow patterns.

(f) Test completed.

(h) Report in preparation.

(5275) PITTSBURGH GENERATING STATION.

- (b) Stone and Webster Engineering Corp., Boston, Mass.
- (d) Experimental, for design.
- (e) A 1/120 by 1/40 vertical scale model of a section of the White River has been constructed for the Indianapolis Power and Light Co. The model represents a section of the river above and below the Pittsburgh plant. Studies are being conducted on bed load movement necessary protective works at the intake, and possible recirculation of hot condenser cooling water.

(f) Tests in progress.

(5276) HOLYOKE POWER DEVELOPMENT.

- (b) Holyoke Water Power Co., Holyoke, Mass.
- (d) Experimental, for design.
- (e) A 1/15 scale sectional model of the gate house structure at the canal entrance was constructed in the 3 foot glass sided flume. Studies were made of forces on various sections including gates and flow and velocity patterns were studied. The experimental work involved representatives of Stone and Webster, Holyoke Water Power and Alden Hydraulic Laboratory.

(f) Tests completed.

(h) Report in preparation.

(5277) LAKE ONTARIO INTAKE.

- (b) Metcalf and Eddy, Inc., Boston, Mass.
- (d) Experimental, for design.
- (e) A 1/17 scale model of a section of submerged intake pipe was installed in a 12 ft. wide flume for the Monro County Water Authority in order to evaluate forces and movement of pipe sections as a result of combined lake currents and storm induced waves.

(f) Tests completed.

(h) Report submitted.

(5278) METER CALIBRATIONS.

- (b) Potter Aeronautical Corp., Union, N. J.
- (d) Experimental, for design.
- (e) Calibration of turbine type flow meters from 2" to 24" in diameter of both the volume and mass flow design have been calibrated. Piping arrangements include standard loop tests and variations such as tandem mounting.

(f) Tests in progress.

(5279) METER CALIBRATIONS.

- (b) ITT General Controls, Warwick, R. I.
- (d) Experimental, for design.
- (e) Calibration of flow tubes in a range of sizes from 6" to 48" has been carried out. Field piping as well as standard test loop installation have been used.

(f) Tests in progress.

UNIVERSITY OF CALIFORNIA, Institute of Industrial Cooperation, Department of Engineering.

(3680) OPTIMIZATION OF WATER RESOURCES DEVELOPMENT.

- (b) Water Resources Center, Univ. of California.
- (c) Prof. Warren A. Hall, Univ. of California, Los Angeles, California 90024.
- (d) Theoretical; basic.
- (e) Mathematical procedures are being developed, refined, and adapted for optimization of the development of water resource systems.
- (g) Several models have been developed for the treatment of major elements and subelements of the problem including: aqueduct capacity determination, and the corresponding cost allocations, the multiple purpose single reservoir project, the deterministic project staging problems, hydroelectric pumped storage optimization, and similar problems.

- (h) "A Method for Allocating Costs of a Water Supply Canal," W. A. Hall, Journal of Farm Economics, Vol. XLV, No. 4, November, 1963.
- "Estimating Flood Probabilities within Specific Time Intervals," W. A. Hall and D. T. Howell, Journal of Hydrology, Vol. 1, pp. 265-271, Amsterdam, 1963.
- "The Optimization of Single Purpose Reservoir Design with the Application of Dynamic Programming to Synthetic Hydrology Samples," W. A. Hall and D. T. Howell, Journal of Hydrology, Vol. 1, pp. 355-363, Amsterdam, 1963.
- "Optimum Design of a Multiple - Purpose Reservoir," W. A. Hall, Journal of Hydraulics Division (ASCE), Vol. 4, July, 1964.

(3681) HYDRAULICS OF SURFACE IRRIGATION.

- (b) Agricultural Experiment Station, Univ. of Calif., Davis, California.
- (c) Prof. W. A. Hall, Univ. of Calif., Los Angeles, Calif. 90024.
- (d) Theoretical and experimental; basic and design.
- (e) An investigation in the hydraulic characteristics of surface irrigation with particular reference to design of surface irrigation systems.
- (g) An analysis of the design of levees for border irrigation is treated in detail to improve both irrigation efficiency and farm operations efficiency.
- (h) "A Functional Analysis of Levees for Border Irrigation Systems," W. A. Hall, accepted for publication, Transactions ASAE, St. Joseph, Michigan.

UNIVERSITY OF COLORADO, Department of Civil Engineering.

(4639) WAVE REFLECTION STUDIES.

- (b) Laboratory project.
- (c) Dr. Warren DeLapp, Department of Civil Engineering, University of Colorado, Boulder, Colorado 80304.
- (d) Experimental, basic research, for Master's thesis.
- (e) Studies are being made of the reflection and transmission of artificially generated waves at submerged barriers and sills of various shapes. Investigations completed have included a flat sill with a vertical face, a thin plate at angles varying from 30° to 90° with the horizontal, and combinations of quarter-cylinders.
- (f) Suspended.
- (g) Empirical relationships have been developed for wave transmission and reflection for different sills. In general the most important factor is the depth of submergence of the sill and flatter waves were found to be reflected more than steep waves. Decreasing the sill length increases the wave transmission and decreases the energy losses.
- (h) M. S. Theses available on loan from the University of Colorado Library, Boulder, Colorado:
 "Transmission and Reflection of Deep Water Waves from a Submerged Sill", by Gerald W. May.
 "Reflection and Damping of Water Waves from a Submerged Barrier", by A. P. Verma.
 "Transmission and Reflection of Deep Water Waves at a Breakwater" by M. C. Mlekush.

UNIVERSITY OF CONNECTICUT, School of Engineering.

- (5489) BOUND-ROCK EROSION PROTECTION FOR HIGHWAY DRAINAGE DITCHES.
- (b) Connecticut State Highway Department.
- (c) Prof. C. J. Posey, Box U - 37, Univ. of Conn., Storrs, Conn. 06268.
- (d) Experimental, applied.
- (e) Develop application of scientific erosion-protection method to highway ditches. Experi-

ments will provide necessary design data and develop construction methods for low-cost installations.

- (5490) RECOVERY OF DEPTH OF SCOUR FLOATS RELEASED DURING FLOODS.

- (b) Department of Civil Engineering.
- (c) Prof. C. J. Posey, Hydraulics Research Laboratory, Box U - 37, Univ. of Conn., Storrs, Conn. 06268.
- (d) Field investigation; for master's thesis.
- (e) Floats devised by W. B. Moeller were released in Connecticut and Willimantic Rivers during spring 1964 peak flows. Floats were brightly marked and had instructions and a return postcard visible from the outside. A float capable of reporting by radio is now being designed.
- (g) Recovery percentage to date only 4% from locations tested.

- (5491) FLOW IN A WIDE FLAT TRIANGULAR CHANNEL.

- (b) Laboratory project.
- (c) Prof. C. J. Posey, Box U - 37, Univ. of Conn., Storrs, Conn. 06268.
- (d) Experimental, basic.
- (e) Measurement of water-surface configuration approaching drop-off at the end of a smooth channel with horizontal grade line. Importance of lateral components is evident but unaccounted for in presently available theories. Turbulence intensity seems uniform over entire width.
- (g)

- (5492) DISCHARGE FROM CIRCUMFERENTIAL WEIRS.

- (b) Department of Civil Engineering.
- (c) Prof. C. J. Posey, Box U - 37, Univ. of Conn., Storrs, Conn. 06268.
- (d) Experimental; master's thesis.
- (e) Head measurements and nappe measurements for water flowing out of vertical pipes and spilling out over their horizontal peripheries.

CORN BELT BRANCH, 108 Soils Building, University of
Minnesota, St. Paul, Minn., Dr. C. A. Van Doren, Branch
Chief.

(66) HYDROLOGIC STUDIES, RALSTON CREEK WATERSHED.

See Iowa Institute of Hydraulic Research,
page 40.

(1723) THE HYDRAULICS OF CONSERVATION STRUCTURES.

See St. Anthony Falls Hydraulic Laboratory
Projects Nos. 111, 1168, 1929, and 2386.
See also U. S. Department of Agriculture,
Agricultural Research Service, Soil and
Water Conservation Research Div., Southern
Plains Branch, Project No. 4335, and Illinois
State Water Survey Division Project No. 1865.

- (b) Cooperative with the Minnesota Agricultural
Experiment Station, the St. Anthony Falls
Hydraulic Laboratory, and the Illinois State
Water Survey.
- (c) Mr. Fred W. Blaisdell, Hydraulic Engineer,
St. Anthony Falls Hydraulic Laboratory,
3rd Ave. S. E., at Mississippi River,
Minneapolis, Minnesota 55414.
- (d) Experimental; applied research for develop-
ment and design.
- (e) Research dealing with the design, con-
struction, and testing of structures for
conserving and controlling soil and water
are carried out. Studies during the past
year have been concerned with the two-way
drop inlet for closed conduit spillways.
The width of this drop inlet is equal to
the barrel diameter. Its length varies.
Water flows only over the two sides. The
end walls support a horizontal plate over
the drop inlet which acts as an anti-vortex
device. The overhang of the plate supports
a trash guard. Tests are conducted using
both water and air as the model fluid to
determine the performance, loss coefficients,
and pressure coefficients for the drop inlet.
Cooperation with and co-ordination of the
tests at the Stillwater, Oklahoma, Outdoor
Hydraulic Laboratory and the Illinois State
Water Survey is maintained.
Additional work on the two-way drop inlet
concerns the effect of low-level orifices
on the performance of the spillway.
A square drop inlet having a hood barrel
entrance is being tested to determine
entrance loss coefficients for various drop
inlet sizes and heights and various barrel
slopes. Previous tests have evaluated the
performance of this type of inlet.
- (g) If the anti-vortex plate is too low,
undesirable orifice flow will control the
discharge. If the anti-vortex plate is too
high, harmful vortices will form under the
plate. Rules for determining acceptable
plate heights have been determined. The
overhang of the plate must be greater than
a certain minimum to insure satisfactory
performance. The action of the two-way
drop inlet is that of a self-regulating
siphon. The tests using air agree with the
results obtained from the water tests and
are much easier to perform. Air is used as
the model fluid only for the condition of
full conduit flow.
Tests on the hood drop inlet have shown that
the hood barrel entrance can be used to
reduce the minimum required height of the
drop inlet. Minimum sizes of drop inlet and
anti-vortex devices have been determined.
Tests of low-stage orifices in the two-way
drop inlet have shown that improper location
and improper proportioning of the orifices
can prevent priming of the spillway. The
proper location of the orifices and the
sizes of the orifices for satisfactory spill-
way performance have been determined.

(2316) RUNOFF FROM SMALL AGRICULTURAL AREAS IN
ILLINOIS.

See University of Illinois, Department of
Agricultural Engineering, page 34.

(4264) HYDROLOGIC STUDIES ON AGRICULTURAL
WATERSHEDS IN WISCONSIN.

- (b) Laboratory project, cooperative with the
Wisconsin Agricultural Experiment Station
and the Wisconsin Valley Improvement Co.
- (c) Mr. N. E. Minshall, Hydraulic Engineer,
P. O. Box 4248, Madison, Wisconsin.
- (d) Field investigation and office analysis.
- (e) Various records of runoff, ground water,
precipitation and climatic factors, soil
moisture, land use, and agricultural
conditions and practices are maintained for
19 agricultural watersheds ranging in size
from 23 to 11,000 acres in the vicinity of
Fennimore, Colby and at other locations in
southwestern Wisconsin. Analyses are made
to evaluate the factors affecting flood
flows, hydrograph characteristics, and the
yield of stream flow.

(4265) PRECIPITATION CHARACTERISTICS INFLUENCING
RUNOFF FROM AGRICULTURAL WATERSHEDS ON THE
UNGLACIATED ALLEGHENY PLATEAU.

- (b) Laboratory project, cooperative with Ohio
Agricultural Experiment Station.
- (c) Mr. L. L. Harrold, Supervisory Hydraulic
Engineer, ARS, Coshocton, Ohio.
- (d) Field investigation and office analysis.
- (e) To develop methods of characterizing
watershed precipitation related to runoff
rates and volumes and to evaluate "normalcy"
of sample periods.
- (g) Records of dense network of rain gages are
being analyzed to determine network
specifications for characterizing rainfall
for runoff rates and volumes. Shielded and
tilted catchment surfaces of rain gages
have been installed in the field along with
wind recording apparatus for studying the
effect of wind on the rain gage catch and
how the latter evaluates the rainfall on
sloping land surfaces of a single aspect.

(4266) SURFACE RUNOFF AND INTERFLOW STUDIES IN THE
UNGLACIATED ALLEGHENY PLATEAU.

- (b) Laboratory project, cooperative with the
Ohio Agricultural Experiment Station.
- (c) Mr. L. L. Harrold, Supervisory Hydraulic
Engineer, ARS, Coshocton, Ohio.
- (d) Field investigation and office analysis.
- (e) To evaluate the factors affecting the
volume of storm surface runoff and interflow
from various combinations of upland watershed
soil, cover, and treatment, and to study the
basic factors affecting the hydrograph of
these flows under various soil-cover
combinations.
- (g) Work is continuing on these studies. Storm
flow totals from all unit source watersheds
along with specific watershed and climatic
parameters have been assembled for all the
major storm runoff periods of record.
Computer analysis of these data is being
made to test for parameter significance.

(4267) STUDIES OF RUNOFF FROM COMPLEX WATERSHEDS
IN THE UNGLACIATED ALLEGHENY PLATEAU.

- (b) Laboratory project, cooperative with the
Ohio Agricultural Experiment Station.
- (c) Mr. L. L. Harrold, Supervisory Hydraulic
Engineer, ARS, Coshocton, Ohio.
- (d) Field investigation and office analysis.
- (e) To determine how flows from incremental
areas combine to produce hydrographs of
stream flow on larger complex watersheds;
determine the effects of climate and
watershed characteristics on rates and
amounts of runoff; and develop methods for
predicting the magnitude and frequency of

- (g) flows from ungaged watersheds. Work is continuing on these studies. Preliminary analysis showed that the summation of flow from incremental areas accounted for, at the best, only 70 percent of the storm flow measured for the larger complex watershed. Base flow was at a minimum. Interflow studies are being made to evaluate the magnitude and timing of this quick return flow as a factor in flood stream flow. Geologic investigations of aquifers contributing to stream flow are included in the study of the effects of watershed characteristics and management of stream flow. Their effect is an important factor, as runoff volumes increase rapidly with watershed size up to areas of 1,000 acres. A small watershed has been thoroughly instrumented to identify and evaluate shallow-depth interflow.
- (h) "Black Locust for Fence Posts", R. E. Youker, Journal Soil and Water Conserv. Vol. 19, No. 14, p. 146, July-August, 1964.
- (4268) STUDIES IN SUBSURFACE HYDROLOGY IN THE UNGLACIATED ALLEGHENY PLATEAU.
- (b) Laboratory project, cooperative with the Ohio Agricultural Experiment Station.
- (c) Mr. L. L. Harrold, Supervisory Hydraulic Engineer, ARS, Coshooton, Ohio.
- (d) Field investigation and office analysis.
- (e) To evaluate ground-water and interflow contributions to stream discharge of agriculture watersheds and the recharge to aquifers under various watershed and climatic conditions.
- (g) Work is continuing on geologic mapping for identifying and evaluating aquifer flow to stream discharge. Catchment areas of these contributing aquifers is being mapped. Studies of interflow have been started on the upland watersheds to help account for that storm flow at the complex watershed runoff gages not measured as upland surface runoff.
- (4269) MOISTURE REGIMES OF SOILS IN THE UNGLACIATED ALLEGHENY PLATEAU.
- (b) Laboratory project, cooperative with the Ohio Agricultural Experiment Station.
- (c) Mr. L. L. Harrold, Supervisory Hydraulic Engineer, ARS, Coshooton, Ohio.
- (d) Field investigation and office analysis.
- (e) To maintain the soil moisture inventory of agricultural watersheds; to evaluate the effect thereon of soil, land use, and climate; to develop methods of estimating soil moisture quantities under various land use and climatic conditions; and to determine the influence of frozen soil and frost structure on water movement.
- (g) Nuclear soil-moisture equipment is now providing good data on soil moisture down to 90-inch depths. They show material variations in moisture within a small watershed. Presently, methods of evaluating watershed soil moisture are being studied. Effect of vegetation of different rooting depths on soil moisture is being evaluated. Deep-rooted crops extract moisture to depths unaffected by shallow-rooted crops. In dry seasons, the former consumes more water than the latter, resulting in less percolation to ground water reservoirs. Lysimeters, 8 feet deep and 1/500 acre area of undisturbed soil record weight changes and percolation.
- (h) "Land Use, Soil Type, and Practice Effects on the Water Budget," by F. R. Dreibelbis and C. R. Amerman, Jour. Geophys. Res. Vol. 69, No. 16, pp. 3387-3393, Aug. 1964.
- "Evidence of Errors in Evaluation of Dew Amounts by the Coshooton Lysimeters," L. L. Harrold and F. R. Dreibelbis, IASH, Pub. 65, pp. 425-431, Mar. 1964.
- "Soil Moisture Sampling Plan for Watersheds", J. L. McGuinness and J. B. Urban, ARS 41-87, Feb. 1964.
- (4270) CHARACTERISTICS OF FLOW IN IRRIGATION FURROWS.
- (b) Laboratory project in cooperation with the Missouri Agricultural Experiment Station.
- (c) Dr. C. A. Van Doren, Chief, Corn Belt Branch, Univ. of Minnesota, St. Paul, Minnesota.
- (d) Experimental and field investigations, both basic and applied.
- (e) The purpose of the study is to investigate the hydraulics of flow in irrigation furrows, as influenced by furrow shape, slope, roughness, and rate of flow. Develop engineering techniques that will provide maximum effective control and management of irrigation water.
- (f) Completed.
- (g) The study showed that roughness coefficient was a function of the depth, hydraulic radius, velocity, and Reynolds number. The roughness coefficient decreased with an increase in each of these four variables. For the trapezoidal furrow, the roughness coefficient was higher than for the triangular furrow with the same degree of retardance.
- (h) "Characteristics of Flow in Trapezoidal and Triangular Irrigation Furrows," by J. F. Thornton and R. P. Beasley, Missouri Agr. Expt. Sta. Bulletin No. 855, March 1964.
- (4271) PLASTIC-LINED MOLE DRAIN STUDIES.
- (b) Laboratory project in cooperation with the Ohio Agricultural Experiment Station.
- (c) Mr. James L. Fouss, Research Agricultural Engineer, Agricultural Engineering Dept., Ohio State University, Columbus, Ohio.
- (d) Experimental and field investigations, both basic and applied.
- (e) The purpose of these investigations is to improve plastic mole drainage techniques and test the effectiveness of other subsurface and surface drainage systems. Tile, mole and other subsurface drainage systems are developed and their effectiveness determined.
- (g) The work is continuing on improving plastic mole drainage materials and installation equipment, and on the effectiveness of other subsurface and surface drainage systems. The most recent field test results on thin-walled plastic mole drain liners indicate that 30 inches is a minimum drain depth to prevent damage to the drains by farm field operations, such as plowing.
- (h) "Automatic Grade Control for Subsurface Drainage Equipment," by J. L. Fouss, R. G. Holmes and G. O. Schwab. Transactions of the ASAE, Vol. 7, No. 2, pp. 111-113, 1964.
- "Research on Plastic-Lined Mole Drains in the United States," by J. L. Fouss and G. O. Schwab. Vth International Congress of Agricultural Engineers Transactions, Lausanne, Switzerland, Sept. 21-27, 1964.
- "Experimental Plastic Drains," by J. L. Fouss and N. R. Fausey, Ohio Farm and Home Research, Vol. 49, No. 4, pp. 54-55, July - August, 1964.
- (4273) SURFACE AND SUBSURFACE DRAINAGE.
- (b) Laboratory project in cooperation with the Minnesota Agricultural Experiment Station.
- (c) Mr. Lee Hermsmeier, Agricultural Engineer, North Central Soil Conservation Field Station, Morris, Minnesota.
- (d) Experimental and field investigations, both basic and applied.
- (e) The purpose of these investigations is to develop engineering techniques that will provide maximum effective control and management of water. Techniques are developed for managing surface water flow through land forming and surface drainage systems. Tile, mole and other subsurface drainage systems are developed and their effectiveness determined.
- (g) Work is continuing on land forming and the development of improved surface drainage

systems, the effectiveness of field diversions, improved plastic mole drainage techniques and effectiveness of other subsurface drainage systems.

(4274) NATIONAL SUMMARIZATION AND ANALYSIS OF RUNOFF AND SOIL-LOSS DATA.

See Purdue University, Agricultural Engrg. Dept., Project No. 3808.

- (b) Laboratory project, cooperative with the Purdue Agricultural Experiment Station.
- (c) Mr. W. H. Wischmeier, Research Statistician, ARS, Agricultural Engineering Department, Purdue University, Lafayette, Indiana.
- (d) Data analyses, applied research.
- (e) Objectives of the national data summarization and analysis project are (1) to consolidate all available past, current, and future runoff, soil loss and related data in standardized form to make them available for application of current methods of hydrologic and statistical analyses; (2) to analyze the data on an over-all basis, with special emphasis on identification and evaluation of significant factor interactions; and (3) to develop bases for prediction of runoff and soil losses from different landscapes under various land use and management conditions. In analyses of the assembled data, special emphasis is directed toward identification and evaluation of factors and interaction effects responsible for the frequent wide differences in results of localized studies at various locations. Over-all results are reduced to charts and tables readily usable by application technicians.
- (g) In studies at 47 locations, average annual runoff from cropped plots ranged from 3 to 36% of rainfall. Amount of runoff was influenced by soil properties, slope, cropping system, productivity level, residue management, tillage methods, and intercrops. On silt loams and silty clay loams, it decreased significantly with increases in percent organic matter. For other soils, percentages of sand and clay were more influential. Runoff per unit area increased with percent slope - with corn the relationship was curvilinear at all crop stages, with small grain or meadow cover it was linear.
- (h) "Relation of Field-Plot Runoff to Management and Physical Factors", by W. H. Wischmeier, Agronomy Abstracts 1964, Amer. Soc. Agron., p. 51.

(4275) BASIC MECHANICS OF RAINFALL, RUNOFF, SOIL MOVEMENT, AND LOSS.

See Purdue University, Agricultural Expt. Station, Project No. (4182).

- (b) Laboratory project, cooperative with the Minnesota and Purdue Agricultural Experiment Stations.
- (c) Dr. L. D. Meyer, Agricultural Engineer, ARS, Agricultural Engineering Building, Purdue Univ., Lafayette, Indiana.
- (d) Experimental; laboratory investigations, basic research.
- (e) Fundamental investigations of the mechanics of rainfall and runoff erosion are conducted at two Corn Belt Branch locations. At Morris, Minnesota, C. K. Mutchler and R. A. Young are using a 40-foot drop tower for studies of raindrop splash patterns as affected by drop size, surface irregularity, water depth, target softness, and target inclination. The pressure distribution at impact is also being investigated. At Lafayette, Indiana, the effect of slope steepness, runoff rate and particle size on erosion by rainfall and/or runoff is being investigated. Non-cohesive glass spheres (50-500 micron) were used initially, with sands, silts, and soils to follow.
- (g) High-speed movies of drops at impact showed that the splash crater became wider, higher,

and more outward as drop size increased. Increased surface roughness, softness, and water depth generally decreased the resulting splash.

Runoff erosion increased as slope steepness and runoff rate increased and as particle size decreased. Strong evidence of critical limits of these variables below which no appreciable erosion occurred was found. The resulting soil erosion relationships were similar to comparable sediment transport and wind erosion relationships.

(h) "When a Raindrop Strikes," USDA, ARS, Agricultural Research, 12: 8, 9, Nov. 1963. "Mechanics of Soil Erosion by Rainfall and Runoff as Influenced by Slope Length, Slope Steepness and Particle Size," by L. D. Meyer. Ph.D thesis, Purdue Univ., Lafayette, Indiana, June 1964.

(4276) IMPROVED PRACTICES FOR CONTROL OF RUNOFF AND EROSION.

- (b) Laboratory project in cooperation with the Purdue Agricultural Experiment Station.
- (c) Mr. J. V. Mannering, Soil Scientist, ARS, Department of Agronomy, Purdue University, Lafayette, Indiana.
- (d) Experimental; field investigations, applied research.
- (e) The purpose of these studies is to determine the effects of soil properties, slope characteristics, type and extent of canopy cover, quantity and management of crop residues, seedbed and tillage practices, and various factor interactions on infiltration and erosion. Replicated tests are conducted on selected plots on Purdue-owned and privately-owned farms in Indiana and adjoining states under simulated rainfall applied with the ARS-Purdue "Rainulator".
- (g) Wheeltrack planting corn on rough-plowed land and cultivating it only when needed to destroy surface crusts substantially reduced both runoff and erosion throughout the entire growing season and increased available soil moisture in periods of deficient rainfall. The studies showed, however, that the benefits derived from this practice: (1) are greatest immediately following good quality sod, (2) diminish progressively with successive years of corn even when abundant residues are incorporated each year, and (3) are much less significant on land from which crop residues have been removed. Corn yields were not significantly affected by the reduction in tillage.
- (h) "Erosion-Control Effectiveness of Rotation Meadows", by J. V. Mannering, L. C. Johnson, L. D. Meyer and B. A. Jones. Jour. Soil and Water Cons. 19: 91-95, June 1964. "The Effect of Minimum Tillage for Corn on Infiltration and Erosion", by J. V. Mannering, L. D. Meyer and C. B. Johnson. Agronomy Abstracts 1964, Amer. Soc. Agron., p. 49. "Effects of Various Rates of Surface Mulch on Infiltration and Erosion", by J. V. Mannering and L. D. Meyer. Soil Sci. Soc. Amer. Proc. 27(1): 84-86, 1963. "Crop Residues and Surface Mulches for Controlling Erosion on Sloping Land Under Intensive Cropping", by L. D. Meyer and J. V. Mannering. Trans. ASAE 6(4): 322, 323, 327, 1963.

(4277) SOIL ERODIBILITY DETERMINATIONS.

- (b) Laboratory project, cooperative with the Purdue, Iowa and Minnesota Agricultural Experiment Stations.
- (c) Mr. W. H. Wischmeier, Research Statistician, ARS, Agricultural Engineering Dept., Purdue University, Lafayette, Indiana.
- (d) Experimental; laboratory and field investigations, basic and applied.
- (e) The purpose is to investigate differences in the erodibility of soils; identify and evaluate the soil properties and profile characteristics that influence erodibility:

- and, if possible, derive an equation that expresses the functional relationship of soil erodibility to these variables. The equation would serve as a means of computing locational values of the soil-erodibility factor in the universal erosion equation. Both "in situ" measurements on field plots and laboratory measurements on small, disturbed soil samples are made under simulated rainfall and related to laboratory analyses of the soils.
- (g) The studies have shown that the erodibility of a soil is not fully determined by those soil properties considered in standard soil-series classifications. The erodibility of Corn Belt soils generally increased with increases in silt content and decreased with increases in sand content, but differences in organic matter content, aggregation, dispersion ratio, and other variables resulted in broad ranges of erodibility within standard textural classes. Interactions of properties that affect infiltration rate and permeability with those that resist dispersion and transport were found to be highly significant. Efforts to develop a dependable soil-erodibility estimating equation are continuing.
- (h) "Relative Erodibility of Three Loess-Derived Soils in Southwestern Iowa", by B. L. Schmidt, W. D. Shrader, and W. C. Moldenhauer. Soil Sci. Soc. Amer. Proc. 28: 570-574, 1964. "The Erodibility of Some Indiana Soils", by T. C. Olson, J. V. Mannering and C. B. Johnson. Proc. Ind. Acad. Sci. 72: 319-324, 1963. "Applicator for Laboratory Rainfall Simulator", by C. K. Mutchler and W. C. Moldenhauer. Trans. ASAE 6:220-222, 1963.
- (4278) RAINFALL ENERGY AND SOIL EROSION RELATIONSHIPS.
- (b) Laboratory project, cooperative with the Illinois Agricultural Experiment Station.
- (c) Mr. J. S. Rogers, Agricultural Engineer, ARS, Turner Hall, Univ. of Illinois, Urbana, Illinois.
- (d) Experimental; field investigation, basic research.
- (e) Raindrops were photographed to determine sizes and impact energies. Runoff was measured and soil loss determined from fallow and continuous corn plots. Various characteristics of rainstorms are being related to the resulting erosion.
- (g) Erosion-producing rainstorms have been limited during this research. Data collection is completed and analysis is underway. Improved runoff measuring and erosion sampling equipment has been developed.
- (h) "A Device for Controlling Electrical Circuits by Rainfall Rate", by L. C. Johnson and H. B. Puckett, Soil Sci. Soc. Am. Proc. 27: 472, 1963. "Improved Measuring and Sampling Equipment for Sediment-Laden Runoff", by J. A. Replogle and L. C. Johnson, Trans. ASAE 6: 259-261, 1963.
- (4279) RUNOFF AND EROSION STUDIES IN IOWA.
- (b) Laboratory project, cooperative with the Iowa Agricultural Experiment Station.
- (c) Dr. W. C. Moldenhauer, Soil Scientist, ARS, 225 Agronomy Bldg., Iowa State University, Ames, Iowa.
- (d) Experimental; field investigations, applied research.
- (e) Purpose is to evaluate soil and crop management practices in relation to water management and erosion control on the major Iowa soils. Runoff, soil loss and related data, under natural rainfall, are taken on fractional-acre plots on Grundy, Ida and Carrington silt loam soils.
- (g) Consistent high crop productivity and good management of abundant residues have very effectively reduced soil erosion from both small grain and corn during intense rains that caused quite severe erosion on the check plots. However, the effectiveness of large amounts of corn residue turned under has not equaled that of a good quality sod turned under before corn.
- (4280) RUNOFF AND EROSION STUDIES ON THE SLOPING LANDS OF WISCONSIN.
- (b) Laboratory project, cooperative with the Wisconsin Agricultural Experiment Station.
- (c) Mr. R. E. Taylor, Soil Scientist, ARS, P. O. Box 6, Lancaster, Wis.
- (d) Experimental; field investigations, applied research.
- (e) After more than 30 years of measurements of runoff and soil loss from field plots under natural rain on steeply sloping Fayette soil near LaCrosse, Wisconsin, all work at that location was terminated at the close of the 1963 crop season.
- (g) A 30-year summary report of runoff and erosion studies in Wisconsin is being prepared for publication as a USDA technical bulletin.
- (h) "Corn Stover Mulch for Control of Runoff and Erosion on Land Planted to Corn After Corn," by R. E. Taylor, O. E. Hays, C. E. Bay and R. M. Dixon. Soil Sci. Soc. Amer. Proc. 28(1): 123-125, 1964.
- (4281) RUNOFF AND EROSION STUDIES IN THE MIDWEST CLAYPANS.
- (b) Laboratory project, cooperative with the Missouri Agricultural Experiment Station.
- (c) Mr. Fred D. Whitaker, ARS, Agricultural Engineering Dept., Univ. of Missouri, Columbia, Missouri.
- (d) Experimental; field investigation, applied research.
- (e) To evaluate effects of soil treatments, tillage practices and supplemental irrigation on runoff and erosion from Midwest Claypan soils. Measurements of runoff, soil loss and concomitant variables on a series of fractional-acre plots and small watersheds under natural rainfall are continuing.
- (g) Fertilization adequate to produce high crop yields and large quantities of plant residues has greatly reduced the formerly serious soil and water losses from this gently sloping, claypan soil. Preparing seedbeds so that shredded cornstalks remained at the surface resulted in further significant reduction in soil loss from the high-intensity rains. Corn receiving full fertility treatment has been a more efficient user of water than has corn with only starter fertilizer.
- (4282) RUNOFF AND EROSION INVESTIGATIONS IN MINNESOTA UNDER SIMULATED RAIN.
- (b) Laboratory project, cooperative with the Minnesota Agricultural Experiment Station.
- (c) Mr. R. A. Young, Agricultural Engineer, ARS, North Central Soil Conservation Research Center, Morris, Minnesota.
- (d) Experimental; field investigations, applied research.
- (e) Simulated rainstorms of design erosivity, applied in each of three cropstage periods, are used to evaluate the relations of runoff and soil erosion to slope steepness, slope shape, row direction, intensity of cropping, residue management, tillage methods, and other variables in relation to crops that are common in this climatic area. Runoff hydrographs are obtained and changes in soil concentration of the runoff are determined by periodic sampling throughout each test. Tests are conducted on various soils of west-central Minnesota and eastern South Dakota.
- (g) Crops tested in various sequences and at several growth stages have included flax, soybeans, corn and small grain. Initial tests have shown slope shape to be a significant factor in erosion. Effects of tillage methods are being tested in

relationship to associated cloddiness and surface configuration.

See Ohio Agricultural Experiment Station, Dept. of Agricultural Engineering, page 62.

(4307) RESERVOIR FORMULAS AND THE VOLUME-WEIGHT OF RESERVOIR SEDIMENT.

- (b) Laboratory project, cooperative with the Soil Conservation Service and State Agricultural Experiment Stations.
- (c) Mr. H. G. Heinemann, Hydraulic Engineer, Bldg. T-12, P. O. Box 208, Columbia, Missouri.
- (d) Field investigations, development, and office analyses.
- (e) This project provides criteria for more accurate determination of the sediment yield of watersheds from reservoir survey data. The investigations include: (1) Refinement of survey procedures and methods for determining reservoir capacities and sediment volume from reservoir sedimentation survey data; (2) explanation of variations in the volume weight of reservoir sediment; (3) recommendations on determination of the total weight of reservoir sediment; and (4) development of procedures for predicting the volume-weight of sediment in a proposed conservation structure.

(4817) EROSION AND MOISTURE CONSERVATION STUDIES ON BARNES SILTY CLAY LOAM.

- (b) Laboratory project, cooperative with the Minnesota Agricultural Experiment Station.
- (c) Mr. R. E. Burwell, Soil Scientist, ARS, North Central Soil Conservation Research Center, Morris, Minnesota.
- (d) Experimental; field investigations, applied research.
- (e) Field plots under natural rain are used to characterize runoff and erosion on the Barnes soil of the North Central Region and to evaluate moisture conservation aspects of soil and crop management practices. Automatically controlled devices to heat the collecting and measuring equipment enable measurement of runoff from snow-melt and thaw. Soil moisture is measured by neutron probe techniques. Wind direction and velocity are automatically recorded.
- (g) During years of average or below average rainfall for this climatic area, moisture conservation for crop use is of greater concern than soil erosion. The measurements have shown, however, that this soil is highly erodible in periods of concentrated rainfall and that erosion damage is a serious problem. The soil has been very responsive to soil and crop management practices as erosion-control measures.
- (h) "Runoff Plot Design and Installation for Soil Erosion Studies", by C. K. Mutchler, ARS 41-79, August, 1963.

(4825) RESERVOIR SEDIMENTATION STUDIES.

- (b) Laboratory project, cooperative with the Soil Conservation Service and State Agricultural Experiment Stations.
- (c) Mr. H. G. Heinemann, Hydraulic Engineer, Bldg. T-12, P. O. Box 208, Columbia, Missouri.
- (d) Field investigations, development, and office analyses.
- (e) Numerous small reservoirs form the basis for this study. The objectives of this project are: (1) Determine the amounts, rates, and character of sediment yields from agricultural watersheds; and (2) relate sediment accumulation in the reservoirs with sediment yield, precipitation, runoff, watershed characteristics, and cultural practices. Sediment yield and related information are important factors in the planning and design of small reservoirs and other conservation installations.

(5033) DRAINAGE INVESTIGATIONS FOR AGRICULTURAL LANDS.

(5204) HYDROLOGIC STUDIES ON WATERSHEDS IN MISSOURI VALLEY DEEP LOESS.

- (b) Laboratory project, cooperative with the Iowa Agricultural Experiment Station.
- (c) Mr. K. E. Saxton, P. O. Box 208, Columbia, Missouri.
- (d) Field investigations, development, and office analyses.
- (e) Two sets of paired agricultural watersheds are instrumented to observe the hydrologic budget and surface runoff in deep loess. Level terracing will be introduced as a variable on one of the watersheds of one of the pairs; a comparison of level terracing and grass cover will be made on the other pair. Variables observed are precipitation, soil moisture to 20-foot depths, surface flow, ground water recharge and outflow, and evapotranspiration.

(5205) ANALOG STUDIES OF SUBSURFACE DRAINAGE.

- (b) Laboratory project in cooperation with the Ohio Agricultural Experiment Station, Dept. of Agronomy.
- (c) Dr. George S. Taylor, Dept. of Agronomy, Ohio State Univ., 1885 Neil Ave., Columbus 10, Ohio.
- (d) Theoretical and experimental; basic and applied.
- (e) An electrical resistance network analog is used to study the placement of subsurface drain tubes to provide optimum water table control for plant growth.
- (g) Removal of excess rainfall and artesian water from a surface peat horizon, underlain with a thick slowly permeable silt layer, can be better achieved with tile drains on 40-foot spacings in the peat layer than with artesian relief wells into the aquifer.

(5561) EROSION AND MOISTURE CONSERVATION STUDIES IN EASTERN SOUTH DAKOTA.

- (b) Laboratory project, cooperative with the South Dakota Agricultural Experiment Station.
- (c) Mr. C. W. Doty, Agricultural Engineer, ARS, South Dakota State College, Brookings, South Dakota.
- (d) Experimental; field investigations, applied research.
- (e) Field plots under natural rain are used to characterize runoff and erosion on the Poinsett soils of eastern South Dakota and to evaluate moisture conservation aspects of soil and crop management practices. Watersheds are being developed for evaluating improved terrace designs for moisture conservation and erosion control.
- (g) Three years' measurements have shown these soils to be very highly erodible during periods of concentrated rainfall, but to be quite responsive to soil and crop management practices as a means of reducing soil erosion. In this area of about 20 inches average annual rainfall, moisture conservation for crop use is a major problem.

(5562) RESERVOIR TRAP EFFICIENCY.

- (b) Laboratory project, cooperative with the Soil Conservation Service and Iowa State Agricultural Experiment Station.
- (c) Mr. H. G. Heinemann, P. O. Box 208, Columbia, Missouri.
- (d) Field investigation, development, and office analyses.
- (e) The purpose of this research is to evaluate those parameters that affect the sediment trapping ability of water-retarding structures. This will enable prediction of the trap efficiency of structures. Measurements are made of the sediment content of the inflow and outflow and the volume retained in the reservoir. Characteristics

of the sediment, watershed, reservoir, and other parameters are also used in the analyses.

(5563) GULLY EROSION STUDIES IN DEEP LOESS.

- (b) Laboratory project, cooperative with the Iowa Agricultural Experiment Station.
- (c) Mr. Robert F. Piest, P. O. Box 208, Columbia, Missouri.
- (d) Field investigation, development, and office analyses.
- (e) Measurements are being made on several actively-eroding gullies in controlled watersheds in the Missouri Valley deep loess. The objectives are to learn the causes of gully and channel erosion, the rate of this erosion, and the effect of level terraces on gully growth. Measurements include amount eroded, changes in dimensions, surface flow, soil moisture, and ground water elevations.

(5564) EVALUATING INTERFLOW WITHIN CLAYPAN SOILS.

- (b) Laboratory project, cooperative with the Missouri Agricultural Experiment Station.
- (c) Dr. V. C. Jamison, P. O. Box 208, Columbia, Missouri.
- (d) Field investigation, development, and office analyses.
- (e) Field investigations are being conducted to identify and evaluate quantitatively the contribution to surface flow by the return to the surface of moisture infiltrated up the slope. Various lengths of plots and degrees of soil saturation are used.

(5565) RUNOFF FROM CLAYPAN SOIL AREA OF MISSOURI AND ILLINOIS.

- (b) Laboratory project, cooperative with the Missouri Agricultural Experiment Station.
- (c) Mr. Keith E. Saxton, P. O. Box 208, Columbia, Missouri.
- (d) Field investigation, development, and office analyses.
- (e) Precipitation, runoff, pond evaporation and seepage, pan evaporation, and land use are being measured on a 160-A. watershed near McCredie, Missouri. These and other rainfall-runoff data throughout this soil area are being analyzed to evaluate water yield and surface runoff.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

NORTHEAST BRANCH, Plant Industry Station, Beltsville, Maryland, Mr. W. W. Pate, Branch Chief.

(3867) IRRIGATION FACILITIES.

- (b) Cooperative project with the Virginia Agricultural Experiment Station.
- (c) Mr. J. N. Jones, Agricultural Engineer, Agricultural Engineering Dept., Virginia Polytechnic Inst., Blacksburg, Virginia.
- (d) Field investigations.
- (e) Irrigation studies are designed to determine the effect of irrigation practices on the yield and quality of tobacco. Plant response, as measured by Leaf Area Index, is related to consumptive use of water and evapotranspiration.
- (f) This study was initiated in 1961. Only preliminary data are available. Current study includes evaluation to the solar radiation utilization.

(4283) A STUDY OF FLOOD FLOWS AND THEIR EFFECTS ON STREAM CHANNELS.

- (b) Cooperative project with Soil Conservation Service and Cornell University.
- (c) Mr. R. P. Apmann, Hydraulic Engineer, 21 South Grove Street, East Aurora, N. Y.

- (d) Experimental field investigations.
- (e) To determine the important streamflow qualities which materially affect the intensity of attack upon the stream channel periphery material and the variation throughout the flow boundary of forces destructive to the channel periphery material. Investigations are conducted on selected natural reaches of Buffalo Creek and tributaries in the vicinity of East Aurora, New York and on the Pequest River in Warren County, New Jersey.
- (g) Thorough study and analysis are continuing on stream geometry and of hydraulic characteristics of channel improvements and stabilization works constructed by Soil Conservation Service on Buffalo Creek. The analysis of the March 30, 1960 and other floods is being carried out by assembling an atlas of high-water data and by preparing a topographic map showing the contours of the stream channel and of the flood plains. A method is being developed for estimating discharge by using the super-elevation of the water surface in an open channel bend. This method is based on the principle that the transverse difference in water surface at an open channel bend is related to the geometry of the bend and to the velocity head of the flow.

(4284) DEVELOPMENT AND EVALUATION OF METHODS FOR CHANNEL STABILIZATION.

- (b) Cooperative project with Soil Conservation Service and Cornell University.
- (c) Mr. R. P. Apmann, Hydraulic Engineer, 21 South Grove Street, East Aurora, New York.
- (d) Experimental field investigations.
- (e) To develop economical methods for streambank stabilization through observation and measurement of the effectiveness of various vegetative and structural measures in relation to streamflow over a range of streamflow conditions and channel geometry. Principal investigations are conducted on Buffalo Creek and tributaries in the vicinity of East Aurora, New York.
- (g) Valuable information is being gained by observing continuously the past stabilization works in Buffalo Creek and noting the conditions which made repair works necessary.
- (h) "Research Seeks Best Techniques for Stabilizing Stream Channels," by R. P. Apmann. Soil Conservation 29(9): 199-201. April 1964.

(4285) CHANNEL HYDRAULICS AND FLOOD ROUTING IN STEEP MOUNTAIN STREAMS.

- (b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.
- (c) Mr. M. L. Johnson, Hydraulic Engineer, Route 2, Danville, Vermont.
- (d) Experimental field investigations.
- (e) Studies on a 1.5-mile reach of the Sleepers River channel involving determination of: travel speed of controlled waves of different volumes; profiles of natural and controlled waves of different volumes; practical field methods of measuring the friction slope of mountain channels; comparisons between results obtained with flood routing formulas and observed flood wave data; and the relationship between channel efficiency, flow duration curves, and watershed morphology.
- (g) Short reaches within the 1.5-mile reach were found to have a Manning's "n" value of between 0.035 and 0.040 for the bank-full conditions and a maximum of about 0.20 for very low flows. Channel roughness and geometry are intricately related to each other and to the lithology and climate of the watershed. This mountain stream is characterized by a relatively narrow and

deep cross-section. It is postulated that this geometry causes a rapid increase in velocity with increasing discharge, providing the erosional energy required for the eventual attainment of a most probable state. There is an upper limit to roughness in a stream channel, and this is approached in the length of stream studied. Addition of more roughness elements would only create a new bed with similar characteristics. The removal of a number of the element would very probably increase the resistance to flow because it would reduce the phenomena of shielding, in which the elements reduce the frictional effectiveness of one another due to close grouping.

(4286) INFLUENCE OF SNOW AND FROZEN SOIL ON RUNOFF.

- (b) Cooperative project with the Vermont Agricultural Experiment Station, Vermont Water Conservation Board, and Soil Conservation Service and College of Technology of the University of Vermont.
- (c) Mr. M. L. Johnson, Hydraulic Engineer, Route 2, Danville, Vermont.
- (d) Experimental field investigations.
- (e) This study on the 43-square mile Sleepers River Watershed is concerned with the factors influencing the accumulation and melting of snow; the relationship of frozen soil to runoff; and the development of methods for predicting runoff associated with snow melt. Data are collected and analyzed from snow courses, precipitation gages, temperature records, heat budgets, soil moisture and frost measurements, and snow melt in conjunction with streamflow records at nine stations in the subdivided watershed.
- (g) The albedo consistently decreased from a high value in January to a low value at the end of the snowmelt season and was found to be affected by the specific gravity of the snow, the age of the snow, and the number of degree-days above 32° F since the last snow. Snow structure was studied weekly by digging pits during the winter through the snow profile to the ground surface. During the winter the snow was distinctly structured, the temperature variations within the snow profile were relatively large, the temperature at the ground surface remained about constant at 32° F., and the specific gravity increased with depth. During the melt period the temperature within the entire snow profile varied less than 3 to 4 degrees, and the specific gravity situation reversed for its maximum value occurred at the snow surface. As the snow melted from the surface downward, the snow layers became less distinct, finally disappeared, and the snow pack became a homogeneous mass of coarse ice crystals. Until these conditions prevailed, very little free water was found to reach the snowmelt pan placed on the ground surface.

(4287) PRECIPITATION PATTERNS AND CHARACTERISTICS.

- (b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.
- (c) Mr. E. T. Engman, Hydraulic Engineer, Route 2, Danville, Vermont.
- (d) Experimental field investigations.
- (e) The purpose of this study is to develop a method for calculating average precipitation on the 43-square mile Sleepers River watershed and its subdivisions in relation to elevation, storm source and direction; to study the behavior of summer convective storms in the northeast; and to provide information on rainfall depth-area-duration in relation to point rainfall in this part of the northeast.
- (g) In a study to determine how watershed parameters affected rainfall and snow depth, altitude was found to be the most important

variable. Seasonal isohyetal maps show that the variation is synonymous with elevation, the difference in precipitation being greatest in winter and least in summer. The areal randomness of thunder-showers appears to account for the more equitable distribution in the summer. The strong correlation between snow depth and elevation is due to the fact that the higher altitudes have greater snowfall, cooler mean temperatures, and more cloudy days. Though the rough and heavily wooded terrain of the higher altitudes provides abundant shade and shelter from the wind, aspect and exposure appear to have a minor influence on the relation between rainfall or snow depth and elevation in this watershed.

- (h) "Computer Reduction of Precipitation Data," by G. H. Comer and W. R. Hamon, U. S. Dept. of Agric. ARS 41-89, 38 pp., 1964.

(4288) INFLUENCE OF SOIL AND LAND USE ON STREAMFLOW FROM AGRICULTURAL WATERSHEDS.

- (b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.
- (c) Mr. G. H. Comer, Hydraulic Engineer, Route 2, Danville, Vermont.
- (d) Experimental field investigations.
- (e) Investigations of the influence of land use, climatic factors, and physical characteristics such as soils, geology, and topography upon runoff rates and water yields from the 43-square mile Sleepers River watershed and its important subdivisions to derive relationships for predicting the hydrologic performance of ungaged watersheds in the other parts of the physiographic area.
- (g) The largest water yield and highest peak flow appears to be more related to amount and distribution of poorly drained soils than to the size of watershed, which varies from 116 acres to 43-square miles.

(4289) SUBSURFACE CONTRIBUTIONS TO STREAMFLOW IN SLEEPERS RIVER WATERSHED.

- (b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.
- (c) Mr. G. H. Comer, Hydraulic Engineer, Route 2, Danville, Vermont.
- (d) Experimental field investigations.
- (e) To investigate procedures for separating streamflow into components of surface runoff, return flow, and base flow for storm and annual flows; to investigate the rates, amounts, and seasonal time distribution of subsurface contributions to streamflow; and to investigate the relationship of the physical characteristics of watersheds to baseflow recession equations and to ground-water hydrograph shapes.
- (g) The constant "K" in the basic groundwater recession equation has been found to vary with seasons and with soil types and land use.

(4290) GROUNDWATER ACCRETION AND MOVEMENT IN RELATION TO WATERSHED CHARACTERISTICS.

- (b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.
- (c) Mr. E. T. Engman, Hydraulic Engineer, Route 2, Danville, Vermont.
- (d) Experimental field investigations.
- (e) To develop information on ground water accretion and movement as affected by land use, soils, geology, and topography; and to develop methods for predicting ground water

- accretion and movement in relation to the physical, hydraulic, and meteorological characteristics of the 43-square mile Sleepers River Watershed.
- (4291) INFLUENCE OF LAND USE ON THE HYDROLOGY OF AGRICULTURAL WATERSHEDS IN VIRGINIA.
- (b) Cooperative project with the Virginia Agricultural Expt. Sta., Virginia Polytechnic Inst., and the Soil Conservation Service.
 - (c) Mr. J. B. Burford, Hydraulic Engineer, Agricultural Engineering Department, Virginia Polytechnic Inst., Blacksburg, Va.
 - (d) Experimental field investigations.
 - (e) To provide additional knowledge concerning the disposition of precipitation in agricultural watersheds, and to develop procedures based upon watershed characteristics, climatic factors, and various land use practices for the prediction of flood peaks and seasonal and annual water yields in three physiographic areas. Hydrologic, geologic, soils, plant cover and cultural data are being obtained on 4 unit source watersheds varying in size from 3.5 to 19.3 acres in the Appalachian Valleys and Ridges and on 10 complex watersheds from 182 to 3,054 acres in the Appalachian Valleys and Ridges, Blue Ridge Mountains, and the Piedmont Plateau.
 - (h) "High Accuracy Streamflow Measurements with Low Cost Installations," by J. B. Burford and J. H. Lillard, Trans. ASAE, Vol. 6(4): 276-281.
 - "Silt in Suburbia," by D. E. Whelan and C. S. Britt, Proc. 18th Annual Meeting of SCSA, pp. 263-270, 1963.
- (4292) HYDROLOGIC EFFECTS OF CHISELING SHALLOW SHALE SOIL IN WEST VIRGINIA APPALACHIAN VALLEYS AND RIDGES.
- (b) Cooperative with West Virginia Agricultural Experiment Station and the Soil Conservation Service.
 - (c) Mr. V. O. Shanholtz, Hydraulic Engineer, Agricultural Engineering Dept., Virginia Polytechnic Institute, Blacksburg, Va.
 - (d) Experimental field investigations.
 - (e) The purpose of this study is to determine the effect of chiseling shallow shale subsoil upon rainfall-runoff relationships of small watersheds. Four 10-acre watersheds were calibrated over a period of six years, from the Spring of 1958 to the Fall of 1964. Treatment was applied to two of the four watersheds in September 1964.
 - (h) "Influence of Selected Rainfall Characteristics on Runoff Volume," by V. O. Shanholtz and W. H. Dickerson, Bulletin 497T, West Virginia University Agric. Expt. Sta., 1964.
- (4294) ERODIBILITY OF SOILS IN THE NORTHEAST.
- (b) Laboratory project, cooperative with Maine Agricultural Experiment Station.
 - (c) Mr. Eliot Epstein, Soil Scientist, Univ. of Maine, Orono, Maine.
 - (d) Laboratory and field investigations both basic and applied for development and design.
 - (e) The purpose of these investigations is to obtain fundamental information on the erodibility of Northeast soils and to determine the interrelations of climate, cover (including rock fragments), runoff, and soil loss.
 - (g) Results continue to show increased erosion due to rock removal and beneficial effects of a rotation over continuous potatoes. Progress is being made on a laboratory technique for evaluating soil erodibility using a rainfall simulator.
 - (h) "Runoff and Erosion Losses in Northern Maine," by E. Epstein, W. J. Grant, and R. A. Strucktemeyer. Maine Farm Research I(2): 8-10, 1963.
- (4295) TILLAGE PRACTICES AND DIVERSION TERRACES FOR WATER AND EROSION CONTROL.
- (b) Laboratory project, cooperative with the New York Agricultural Experiment Station, and the Soil Conservation Service.
 - (c) Mr. George R. Free, Soil Scientist, Bailey Hall, Cornell University, Ithaca, New York.
 - (d) Field investigations.
 - (e) The purpose of these investigations is to determine the inter-relation of tillage, topography, climate, runoff and soil loss, and to evaluate the effectiveness of diversion terraces for controlling surface and subsurface flow.
 - (g) Work is continuing on the effectiveness of conventional, mulch and minimum tillage for corn on runoff and erosion from slopes of different steepness and length and on the effect of diversion terraces on surface soil moisture during critical crop growth stages for several sloping soils having seepage problems.
- (4819) DEVELOPMENT AND EVALUATION OF DRAINAGE PRACTICES IN THE NORTHEAST.
- (b) Laboratory project cooperative with the Vermont Agricultural Experiment Station and the Soil Conservation Service.
 - (c) Mr. Joseph Bornstein, Agricultural Engineer, University of Vermont, Burlington, Vermont.
 - (d) Field investigation both basic and applied research.
 - (e) The purpose of this study is to develop and evaluate drainage practices for sloping lands of the Northeast. This involves development of techniques for determining directional components of subsurface water flow before and after installation of drainage treatments. Surface drainage practices are instrumented to measure runoff from rainfall and snowmelt.
 - (f) Instrumentation of this project is completed and one year's data are available on diversion ditch runoff and tile outflow. Extensive piezometric data are also available.
 - (h) "Transistorized Piezometer Water Level Reader," by J. Bornstein and R. R. Alberts. Jour. Agric. Engr. Res. 8: 340-341, 1963.
 - "Ground Water Movement in Poorly Drained Glacial Till Soil," by J. Bornstein. Amer. Soc. of Agr. Engr. Trans. 7(1): 38-41, 45, 1964.
- (4820) HYDROGRAPH LABORATORY.
- (b) Laboratory project. Cooperative efforts on occasion.
 - (c) Mr. H. N. Holtan, Director, Hydrograph Laboratory, ARS, Beltsville, Md.
 - (d) Basic and applied research.
 - (e) The purposes of this project are to evolve and test new concepts, theories and principles for understanding the hydrologic processes on agricultural watersheds; to test and adapt information from various sources for application to water control and related problems encountered in watershed engineering; to conduct special analyses involving ARS data from more than one Station or more than one Branch that can be more adequately carried out at a central location which has available a full-time staff of scientists with specialized training in hydraulics, hydrology, meteorology, and mathematics; and to provide case assistance to field personnel detailed to the Laboratory for specific analyses as requested by the field.
 - (g) The Hydrograph Laboratory is currently performing hydrologic computations with digital computers to simulate watershed performance as affected by various protective measures. In a continuation of the study reported last year, a system was developed for expressing the rising side of a hydrograph, as well as the falling side in terms of the recession storage-flow relationship. It was found that two successive routings of rainfall excess through one-half of the storage derived from the recession curves induces the lag needed to predict the rising

side of the hydrograph. Currently, the U. S. Hydrograph Laboratory is conducting a survey of hydrologic capacities of selected soils occurring on Agricultural Research Service study watersheds. These data are intended for use in computing infiltration curves and watershed retentions. Numerical studies are continuing in the hydraulics of flood flow including both kinematic and kinetic formulations. These computations are programmed for the 1620 computer and are presently adaptable for varied overland flow or for varied flow in prismatic channels. Depth-area duration studies of rainfall expectancies are underway using data from dense network watersheds as supplied by various participating agencies. Distribution patterns for major storms are also under study.

- (h) "Handbook of Applied Hydrology," Section 12, Infiltration, by G. W. Musgrave and H. N. Holtan, contributing authors, edited by Ven Te Chow. McGraw-Hill, Inc. 10074, 1964.
 - "Mathematical Refinement of an Infiltration Equation for Watershed Engineering," by D. E. Overton, USDA ARS-41-99, 11 pp., 1964.
- (4821) EFFECTIVENESS OF STREAM BANK STABILIZATION AND PROTECTION MEASURES IN REDUCING SUSPENDED SEDIMENT LOAD.
- (b) Cooperative project with Soil Conservation Service and Cornell University.
 - (c) Mr. R. P. Apmann, Hydraulic Engineer, 21 South Grove Street, East Aurora, New York.
 - (d) Experimental field investigations.
 - (e) To develop procedures for estimating effectiveness of streambank stabilization and other measures in reducing the sediment discharge of a stream. It is postulated that the total sediment load of a stream is directly related to the mean concentration of the suspended sediment for a flood series, and that changes in time of the mean concentration resulting from installation of streambank stabilization measures are indicative of changes in total sediment load. The streambank stabilization measures are being installed by Soil Conservation Service as part of the authorized flood prevention program in the Buffalo River watershed. Measurements of suspended sediment load concentration and of stream discharges are made for all floods above a certain magnitude.
 - (h) "The Determination of Sediment Yields from Floodwater Sampling," by D. A. Parsons, R. P. Apmann, and G. H. Decker, Internat'l Assoc. Sci. Hydrology 65: 7-15, 1963.
- (4822) A STUDY OF THE MOVEMENT OF COARSE-TEXTURED BED MATERIAL OF TWO NEW YORK MOUNTAIN STREAMS.
- (b) Cooperative project with Soil Conservation Service and Cornell University.
 - (c) Mr. R. P. Apmann, Hydraulic Engineer, 21 South Grove Street, East Aurora, New York.
 - (d) Experimental field investigations.
 - (e) To relate the quantities of transported bed materials to flood discharge rates and durations, to determine applicability of bed load equations in coarse material transport problems and, if appropriate, devise new or revised relationships. In 1963 a stream reach was instrumented and debris basin made larger on the Little Hoosic River near Berlin, New York. In 1964 a stream reach and debris basin were instrumented on Dean Creek, Tioga County, New York.
- (4823) COMPILATION AND PUBLICATION OF SELECTED HYDROLOGIC DATA.
- (b) Cooperative project with various State Experiment Stations and Land Grant Colleges and with the Soil Conservation Service.
 - (c) Mr. H. W. Hobbs, Hydraulic Engineer, Plant Industry Station, Beltsville, Md.
 - (d) Office assembling and processing of current hydrologic data.
 - (e) To provide information on monthly precipi-

tation and runoff, annual maximum discharges and volumes of runoff, and selected runoff events with associated data on rainfall, land use and practices, soils, geology, and antecedent conditions for all current ARS research watersheds in the United States. Hydrologic Data for years 1962, 1963, and 1964 will be published separately at six-month intervals. Hydrologic Data for 1965 and subsequent years will be submitted for publication by August of the following year.

- (5206) DRAINAGE PRACTICES FOR LEVEL AND SLOPING LANDS.
- (b) Cooperative project with the Virginia Truck Experiment Station and the Virginia Agricultural Experiment Station.
- (c) Mr. Truman Goins, Agricultural Engineer, P. O. Box 2160, Norfolk, Virginia.
- (d) Laboratory and field investigations including both theoretical and applied phases.
- (e) Drainage studies for level land include a study of drainage requirements of various vegetable crops with emphasis on the various factors related to high soil water contents and their effect on plant growth. Land-forming will be studied as a means of minimizing the need for surface drains in flat Coastal Plains areas, and for more efficient soil and water management practices on sloping lands of the Piedmont.
- (g) Greenhouse data are available on the effect of different water table levels on growth and water absorption of crops grown on three soils. Further studies are being conducted on maximum soil water tolerance of crops as related to water utilization.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Div.

NORTHERN PLAINS BRANCH, P. O. Box 758, Fort Collins, Colo., Dr. C. E. Evans, Branch Chief.

- (2902) DEVELOPMENT AND IMPROVEMENT OF WATER MEASURING DEVICES.
- Cooperative with Colorado Agricultural Experiment Station. See Colorado State University, Civil Engineering Section, Fort Collins, Colo., page 16.
- (3217) HYDROLOGIC STUDIES OF GROUND WATER IN THE RED RIVER VALLEY OF NORTH DAKOTA.
- (b) Laboratory project.
- (c) Mr. L. C. Benz, Agricultural Engineer, P. O. Box 806, Grand Forks, North Dakota.
- (d) Field investigation. Applied research.
- (e) A field investigation covering more than 200 square miles to determine possible causes for a saline condition on a large area of land. Measurements consist of water tables, artesian conditions, soil and water physical and chemical data.
- (g) Salt-affected soils are caused by high water tables, poor drainage conditions and saline artesian waters. High water tables are caused by precipitation. The salt source is the Dakota sandstone artesian aquifer.
- (4296) HYDRAULICS OF SUB-CRITICAL FLOWS IN SMALL, ROUGH CHANNELS.
- See Colorado State University, Civil Engrg. Section, Project No. 3400.
- (b) Laboratory project, cooperative with the Colorado Agricultural Experiment Station.
- (c) Mr. E. Gordon Kruse, Agricultural Engineer, Hydraulic Laboratory, Colorado State Univ., Fort Collins, Colorado.
- (d) Experimental investigations; basic and applied, portions used for masters and doctoral theses.
- (e) This study is an experimental investigation utilizing a tilting flume in which a small channel 60-feet long is formed by natural

- soil which is fixed in position against movement by chemical spray. A variety of roughness forms can be created on the bed. The relation of roughness dimensions and channel shape to flow resistance is determined for a range of channel slopes and flow depths.
- (f) Inactive.
- (g) Relationships between resistance coefficients and measured roughness dimensions were developed for both laminar and turbulent flows. The transition between these flows was found to occur at a Reynolds number (RV/v) of 500 for these channels. For low Reynolds number flows (Re less than 500) over rough boundaries, normal flow depth was proportional to discharge, viscosity and roughness height and inversely proportional to roughness spacing and channel slope. For turbulent flows, resistance was a logarithmic function of roughness height and flow depth. The standard deviation of bed elevation measurements was used in both cases to represent the effective height of the nonuniform roughness elements. Effects of roughness spacing and channel shape on flow resistance could not be detected for turbulent flows.
- (h) "Effects of Boundary Roughness and Channel Shape on Resistance to Flow of Water in Very Small Open Channels" (ABSTRACT), E. G. Kruse. Diss. Abs. Universal Microfilms, Inc., Ann Arbor, Mich., Vol. XXIII, No. 9, pp. 3295-6, March 1963.
- (4297) COOPERATIVE WATER YIELD PROCEDURES STUDY.
- (b) Laboratory project, cooperative with Soil Conservation Service, USDA, and the Bureau of Reclamation, USDI.
- (c) Mr. A. L. Sharp, (Collaborator), 1697 S. W. 19th, West Linn, Portland, Oregon.
- (d) Office analyses, applied research.
- (e) To develop and test methods for use by field engineers to evaluate the downstream effects of upstream conservation use and treatment of land on water yields of creeks and rivers. The project is one purely of analytic hydrology. The project uses available hydrologic and other data wherever it is available. It secures no new hydrologic data such as streamflow data, climatic data, or land-treatment data. The project is nearing completion.
- (g) Studies have demonstrated that it cannot be proved statistically significant that there are downstream effects on stream flow of upstream conservation treatment and use of land, although it is axiomatic that in subhumid to arid areas such effects must exist. A rational method of evaluating such effects has been developed and tested. A summary of the studies performed and presentation of the rational method will be published through Department of Agriculture media during 1964.
- (4298) COMPARISONS OF RATES AND AMOUNTS OF RUNOFF FROM SMALL SINGLE-COVER WATERSHEDS.
- (b) Laboratory project, cooperative with the Nebraska Agricultural Experiment Station.
- (c) Mr. Frank J. Dragoun, Hydraulic Engineer, ARS-SWC, Hastings, Nebraska.
- (d) Field investigations -- applied research.
- (e) To evaluate the effect of (1) different land use treatment and (2) different crops on the runoff from single crop watersheds in the Central Great Plains, as one of the significant factors influencing runoff from complex watersheds. Replicate 4-acre single crop watersheds in meadow, pasture, cultivated and eroded cultivated land seeded to grass are instrumented with recording rain gages, flumes and waterstage recorders. Six cultivated watersheds are in a wheat-sorghum-fallow rotation. Mulch (subsurface) tillage, on the contour, is practiced. Effects of different crops and land uses on storm runoff rates and amounts are determined by analyzing hydrographs and histograms. Seasonal, annual, and long time effects are determined by analyzing precipitation and runoff data.
- (g) Twenty-four years of record show that runoff from a single crop 4-acre watershed averaged 3.3 inches. During the same period a 4-acre native-pasture yielded 2.0 inches and a native-meadow yielded only 0.25 inches. Rainfall during the period averaged 22.4 inches. These results indicate the relative differences that can be expected in runoff under different land-use practices.
- (4299) RUNOFF AND HYDROGRAPH CHARACTERISTICS OF LARGE MIXED-USE WATERSHEDS.
- (b) Laboratory project, cooperative with the Nebraska Agricultural Experiment Station.
- (c) Mr. Frank J. Dragoun, Hydraulic Engineer, ARS-SWC, Hastings, Nebraska.
- (d) Field investigations -- applied research.
- (e) To determine characteristics of runoff from large mixed-use watersheds as related to, or affected by, precipitation, channel storage, transmission losses to valley alluvium, time of concentration, stream gradient, and watershed size. Three watersheds, in mixed use, 481, 2086 and 3490 acres in size, are instrumented with rain gages, weirs, and stage recorders for observing precipitation and runoff. Transmission losses to valley alluviums are estimated by use of gaged outflow and estimates of inflow from unit source areas of tributary land. These latter estimates are based on gaged rainfall on and runoff from small 4-acre single-use source area watersheds. Hydrographs and histograms are analyzed to obtain watershed retention (infiltration) rates and hydrograph characteristics.
- (g) Twenty-four years of record indicate that average yearly runoff from a conventionally farmed area of 481 acres was 3.3 inches. On a single crop 4-acre area the average was 3.6 inches. Rainfall for the period averaged 22.4 inches. A comprehensive analysis of the 24 years of continuous records is underway.
- (4300) COMPARISON OF RUNOFF AND SEDIMENT YIELDS FROM CONSERVATION AND CONVENTIONALLY FARMED WATERSHEDS.
- (b) Laboratory project, cooperative with the Nebraska Agricultural Experiment Station.
- (c) Mr. Frank J. Dragoun, Hydraulic Engineer, ARS-SWC, Hastings, Nebraska.
- (d) Field investigations -- applied research.
- (e) To determine the effects of conservation farming, land use, climate, and physiography on rates and amounts of runoff and sediment yields. Two 400-odd-acre watersheds, one conventionally farmed and the other conservation farmed, are equipped with recording rain gages, weirs and stage recorders, and sediment samplers, to measure precipitation, runoff, and sediment yields. The two watersheds were operated the same during a calibration period from 1939 to 1947. One was then treated by terracing, contour tillage and seeding eroded cultivated land to grass.
- (g) Current data substantiate previous analyses indicating conservation measures are effective in controlling soil erosion from average rainfall events. Six years of continuous measurement show that annual sediment yield from the area under conservation was 5.4 tons/acre compared with 8.7 tons/acre from the conventionally farmed area or a difference of 38 percent. In 1957, a year of above normal rainfall with intense storms, no significant reduction in sediment yield was realized under conservation practices whereas in 1963, a year of above normal rainfall but no intense storms, the sediment yield from the area under conservation was only 14 percent of that from the conventionally

- farmed area. The significance of kinetic energy of rainfall in sediment yield determinations is indicated.
- (4301) RELATIONSHIP BETWEEN INTENSITY OF GRAZING AND RUNOFF AMOUNTS ON FINE-TEXTURED SOILS.
- (b) Laboratory project, cooperative with South Dakota Agricultural Experiment Station.
 - (c) Mr. Clayton L. Hanson, Agricultural Engineer, Newell Irrigation and Dryland Field Station, Newell, South Dakota.
 - (d) Field investigations -- applied research.
 - (e) To determine the effects of light, moderate and heavy grazing and other factors such as precipitation, antecedent soil moisture, soil frost and snow accumulation, on rates and amounts of runoff from fine-textured range soils in southwestern South Dakota. Replicated plots of about 2 acres in each of the lightly, moderately and heavily grazed pastures are instrumented to observe runoff amounts (stage recorders and H-flumes) rates and amounts of precipitation (recording rain gages), soil moisture, soil frost and vegetative conditions. The studies are being made on the South Dakota Range Experiment Station near Cotton wood, South Dakota.
- (g) Rainfall-runoff events during the first year of study indicate that grazing intensity materially influences range cover and that runoff is normally higher from heavily grazed areas although storm sequences and antecedent moisture conditions can significantly influence the normal trend.
- (h) "Runoff as Affected by Intensity of Grazing on Rangelands." A. L. Sharp, J. J. Bond, J. W. Neuberger, A. R. Kuhlman, and J. K. Lewis, Jour. Soil and Water Conserv. 19(3): 103-106, May-June, 1964.
- (4302) MEDICINE CREEK WATERSHED INVESTIGATIONS.
- (b) Laboratory project, cooperative with the Soil Conservation Service, U. S. Geological Survey, Bureau of Reclamation, and Nebraska Agricultural Experiment Station.
 - (c) Mr. V. I. Dvorak, Hydraulic Engineer, ARS-SWC, Hastings, Nebraska.
 - (d) Field investigations; compilation and analysis of data.
 - (e) Data from this southwestern Nebraska project are being analyzed for the following purposes: (1) To estimate the long-time runoff and sediment yields from 8 years of observed hydrologic watershed data; (2) to determine if acquired runoff, sediment and channel data will adhere to the existing channel regime equations for six runoff stations; and (3) to compile and prepare a publication indicating what data have been collected as part of the cooperative investigations, and where these data may be found.
- (g) The long-time sediment yields for the six watersheds have been computed by three different approaches. In each of these methods, the observed runoff and sediment data for 8 years were used for the projection.
- (4303) SEDIMENT YIELD AS RELATED TO GULLY AND CHANNEL EROSION.
- (b) Laboratory project, cooperative with the Soil Conservation Service, and Nebraska and Kansas Agricultural Experiment Stations.
 - (c) Mr. V. I. Dvorak, Hydraulic Engineer, ARS-SWC, Hastings, Nebraska.
 - (d) Field investigations; compilation and analysis of data.
 - (e) The objectives of this project are: (1) To determine and relate rates of gully and channel erosion to causal factors; (2) to provide basic data on rates of land loss and land depreciation due to gully erosion; and (3) to develop criteria, based upon hydrologic and physical factors, for estimating quantities of sediment derived from gully erosion.
- (g) Results of studies covering an 11-year period indicate that channel slopes and shapes are related to erosion and runoff conditions. It was found that for a unit cross section area, depths of flow, in a gullied channel, increase in a downstream direction but the rate of increase declines with distance downstream from the head-cut. Head cutting erosion in one case was equivalent to 8 percent of the total sediment yield and the material removed from the channel was equivalent to 30 percent of the total sediment yield of the tributary drainage in the 11-year period.
- (4304) SABETHA LAKE WATERSHED SEDIMENTATION STUDIES.
- (b) Laboratory project, cooperative with the Soil Conservation Service and Kansas Agricultural Experiment Station.
 - (c) Mr. V. I. Dvorak, Hydraulic Engineer, ARS-SWC, Hastings, Nebraska.
 - (d) Field investigations and office analysis.
 - (e) The objectives of this study are: (1) To determine the amount, rate, and character of the sediment yields from this 10-square mile watershed in northeast Kansas; (2) to relate sediment accumulation in the reservoir with sediment yield, precipitation, runoff and other watershed characteristics.
- (4306) SEDIMENT DISTRIBUTION IN FLOODWATER RETARDING-TYPE RESERVOIRS.
- (b) Laboratory project, cooperative with the Soil Conservation Service and State Experiment Stations.
 - (c) Mr. Verne I. Dvorak, Hydraulic Engineer, ARS-SWC, Hastings, Nebraska.
 - (d) Theoretical and field investigations, and office analyses.
 - (e) This study was undertaken to improve the design criteria for floodwater retarding-type reservoirs by: (1) determining those factors that influence sediment distribution and evaluating their importance, and (2) deriving and testing methods for predicting the horizontal and/or vertical sediment distribution in floodwater retarding-type reservoirs. This is important in determining the minimum elevation of the principal spillway and the required original capacities of various storage pools.
- (4309) ISOLATION AND RELATIVE EVALUATION OF RUNOFF PRODUCING POTENTIALS OF RANGE SITES OF WESTERN SOUTH DAKOTA.
- (b) Laboratory project, cooperative with the South Dakota Agricultural Experiment Station.
 - (c) Mr. A. R. Kuhlman, Botanist, Newell Irrigation and Dryland Field Station, Newell, South Dakota.
 - (d) Field and laboratory investigations -- applied research.
 - (e) To evaluate relative runoff producing potentials of principal range sites of Western South Dakota including sandy, silty, shallow, thin breaks, panspots, overflow, clayey, and dense clay range sites as characteristic of D-4, D-10, and D-11 soil conservation problem areas in the Dakotas, Montana and Wyoming. To evaluate relatively the same range sites by rainfall simulators. To isolate vegetative factors such as standing vegetation, mulch, root systems and soil factors that cause differences in runoff from different range sites.
 - (h) "Precipitation-Runoff Relationships on Western South Dakota Watersheds," J. W. Neuberger, A. L. Sharp, and A. R. Kuhlman. So. Dak. Farm and Home Res. XV(1): 6-9, Winter, 1964.
- (4310) WATER YIELD AND SEDIMENT ACCUMULATION FROM RANGELAND WATERSHEDS.

- (b) Laboratory project, cooperative with the South Dakota Agricultural Experiment Station.
 - (c) Mr. Clayton L. Hanson, Agricultural Engineer, Newell Irrigation and Dryland Field Station, Newell, South Dakota.
 - (d) Field investigations, applied research.
 - (e) To determine the frequency of water yields of various amounts from rangeland watersheds ranging in size from a few acres to 13,000 acres, and gross sediment yields (volumetric) from the same watersheds, as representative of the D-4, D-10, and D-11 soil conservation problem areas in eastern Montana, Wyoming and the Western Dakotas. Purposes of these studies are to provide data on water yields and information on which to estimate the probable useful life of ponds and reservoirs in the problem areas. The work is being done by gaging precipitation, measuring water yields in stockwater reservoirs, making reservoir sedimentation surveys, and securing data on watershed physical, topographic, ecologic and grazing use factors.
 - (g) Data continue to show that sediment yields from fine-textured soils are double those from the medium textured soils (7.5 tons/acre and 3.7 tons/acre respectively). Similarly, surface runoff from the fine-textured soils has continued to average 4 times that from medium-textured soils. In 1962, 6.1 inches of runoff or 27 percent of the 22.6 inches of precipitation occurred in a 90 acre fine-textured soil area which is the highest percentage measured since the studies were initiated in 1957. The highest runoff during 1962 from the medium-textured soils areas was 6 percent of the annual rainfall.
- (4824) EVAPORATION AND SEEPAGE FROM RANGELAND STOCKPONDS.
- (b) Laboratory project, cooperative with the South Dakota Agricultural Experiment Station.
 - (c) Mr. Clayton L. Hanson, Newell Irrigation and Dryland Field Station, Newell, South Dakota.
 - (d) Field investigations -- applied research.
 - (e) To differentiate total stockpond water dissipation into evaporation and seepage and develop a basis for predicting expected stockpond water losses. The purpose of this study is to aid in the development of practical methods to reduce losses of water from stockponds to provide dependable water supplied for livestock.
 - (g) Data show that the ratio of the total pond evaporation (floating pan) to that from the Class A land pan is 0.64. Seepage and deep percolation in ponds in the medium-textured soils region amount to 55% of the total pond dissipation. In one 12 ac. ft. capacity stockpond the volume of daily seepage loss over a 37-day period averaged 910 cu. ft. per day or an equivalent volume to water more than 600 cows each day. Stockponds on medium-textured soils are continuing to show water losses exceeding inflow up to 80 percent of the time resulting in dry ponds nearly 50 percent of the time.
- (4826) HYDRAULIC CHARACTERISTICS OF PARTIALLY SATURATED POROUS MEDIA.
- See Colorado State University, Civil Engrg. Section, Project No. 4611.
- (b) Laboratory project, in cooperation with Colo. Agricultural Experiment Station.
 - (c) Mr. R. H. Brooks, Agricultural Engineer, Hydraulics Laboratory, Colorado State Univ., Fort Collins, Colorado.
 - (d) Basic research.
 - (e) Certain hydraulic characteristics of porous media must be known for laboratory modeling of complicated field problems involving water movement in soils. Problems involving flow of fluids in partially saturated soils often cannot be solved except by inferences derived from the performance of models. The purpose of the study is to be able to predict from equations how any porous medium will behave with respect to the functional relationship between permeability, degree of saturation (or fluid pressure) when certain media properties are known. A thorough understanding of the way permeability is effected by measurable properties of porous media might eliminate the necessity of selecting a porous medium by trial for use in model studies.
 - (g) A theory showing how the variables capillary pressure, water and air permeability are related to degree of saturation has been developed. Methods and equipment have been developed for measuring these variables using steady state experiments. Verification of the theory with experimental results has been good. It appears that hydraulic properties of partially saturated media can be described by three parameters: the bubbling pressure, P_b ; a measure of the uniformity of the pores in the medium, σ ; and the saturated permeability K .
 - (h) "Hydraulic Properties of Porous Media and Their Relationship to Drainage Design," R. H. Brooks and A. T. Corey. J. Am. Soc. Agric. Eng. 7(1):26-27, 1964.
 - "Hydraulic Properties of Porous Media," R. H. Brooks and A. T. Corey. Colo. State Univ. Hydraulics Paper No. 3:1-27, March 1964.
- (4827) HYDRAULICS OF FLOW IN BORDER CHECK IRRIGATION SYSTEMS.
- (b) Laboratory project, in cooperation with Nebraska Agricultural Experiment Station.
 - (c) Mr. O. W. Howe, USDA-ARS-SWC, P. O. Box 786, Grand Junction, Colorado.
 - (d) Field investigation; applied research, design.
 - (e) This is a study of the operational characteristics of low-gradient border checks on a medium textured soil. It involves measurement of the efficiency of irrigation, uniformity of distribution, effect of uneven grade, kind of crop, stage of crop development, etc., upon irrigation efficiency. Soil moisture samples are taken before and after irrigation at intervals in the length of the run. Continuous measurements are taken of depth of water at these stations throughout the set. The purpose is to obtain relationships regarding the effect of crop retardance, slope, surface configuration, intake rate, on rate of advance of irrigation water. Such relationships will be useful in designing and operating low-gradient border check irrigation systems.
 - (f) Discontinued.
 - (g) Slopes of 0 to 0.05 percent gave highest irrigation efficiencies, around 90 percent, when crop retardance to the flow of water was small. Slopes of 0.10 to 0.15 percent were needed to offset the high retardance caused by fully developed sugar beet foliage.
- (4828) DESIGN DATA FOR LEVEL OR NEARLY LEVEL BENCH IRRIGATION SYSTEMS ON CLAY SOILS IN WESTERN SOUTH DAKOTA.
- (b) Laboratory project, in cooperation with South Dakota Agricultural Experiment Station.
 - (c) Mr. Niel A. Dimick, Agricultural Engineer, Newell Irrigation and Dryland Field Station, Newell, South Dakota.
 - (d) Field investigations. Results will be used for design purposes.
 - (e) This is a study of the operational characteristics of low-gradient border checks on a fine textured soil. It involves measurement of the efficiency of irrigation, uniformity of distribution, and effect of uneven grade, kind of crop, stage of crop development, etc., upon irrigation efficiency. Soil moisture samples are taken before and after irrigation at intervals in the length of the run. Continuous measurements are taken of depth of water at these stations throughout the set. The purpose is to obtain relationships

- regarding the effect of crop retardance, slope, surface configuration, intake rate, on rate of advance of irrigation water. Such relationships will be useful in designing and operating low-gradient border check irrigation systems.
- (g) No significant findings have been obtained as yet since this project was just initiated in 1962.
- (4829) THE INFLUENCE OF RELIEF UPON VEGETATION, SOIL SALTS, AND WATER TABLES IN AN IMPERFECTLY DRAINED GLACIO-LACUSTRINE SALINE AREA OF INTERCONNECTING RIDGES AND DEPRESSIONS IN NORTH DAKOTA.
- (b) Laboratory project.
- (c) Mr. F. M. Sandoval, Soil Scientist, U. S. Field Station, Mandan, North Dakota or Mr. L. C. Benz, Agricultural Engineer, P. O. Box 806, Grand Forks, North Dakota.
- (d) Field investigation; applied research.
- (e) A field experiment of dimensions 450 x 800 feet in a ridge-depression micro-relief area where depressions are non-saline but ridges highly saline. Purpose of study is to determine reasons for the differences in salinity. Evaluated by measurements of ground-water gradients and studies of water chemistry and soil physical and chemical data.
- (f) Terminated.
- (g) Generally, greater leaching occurs in the depressions owing to impounded precipitation. Artesian pressures are present but play a minor role.
- (h) "Chemical and Physical Properties of Soils in a Wet Saline Area in Eastern North Dakota," F. M. Sandoval, L. C. Benz, and R. H. Mickelson. Soil Sci. Soc. Am. Proc. 28(2):195-199, 1964.
- "Microrelief Influences in a Saline Area of Glacial Lake Agassiz: II. On Shallow Ground Water," L. C. Benz, F. M. Sandoval, R. H. Mickelson, and E. J. George. Soil Sci. Soc. Am. Proc. 28(4):567-570, July-August, 1964.
- (4831) LAND FORMING ON SALT-AFFECTED LACUSTRINE SOILS IN THE RED RIVER VALLEY HAVING AN INTERSECTING MINOR RIDGE-DEPRESSION TYPE OF MICRORELIEF.
- (b) Laboratory project.
- (c) Mr. L. C. Benz, Agricultural Engineer, P. O. Box 806, Grand Forks, North Dakota.
- (d) Field experiment; applied research.
- (e) Consists of four 5-acre plots under cultivation in a saline ridge-depression micro-relief area. Two plots are leveled -- one having surface drainage, the other having only internal (tile) drainage (precipitation is impounded). One unleveled plot has internal drainage, the second one has none. Purpose of work is to determine effects of land forming and tile drainage on salt-affected land.
- (4832) A STUDY OF THE FALLING WATER TABLE, SOIL MOISTURE, AND SOIL SALT TRANSLOCATION DURING WINTER MONTHS.
- (b) Laboratory project.
- (c) Mr. L. C. Benz, Agricultural Engineer, P. O. Box 806, Grand Forks, North Dakota.
- (d) Field experiment; basic research.
- (e) Experiment consists of two treatments (straw mulch and fallow) each replicated 3 times. Field plots are 60' x 60'. Measurements obtained are; soil moisture (neutron method), water tables, soil temperatures, freezing depth, water and soil physical and chemical data. Purpose of the experiment is to determine translocation of water table waters which recede during the winter months.
- (f) Field work terminated. Report not yet available.
- (4833) RELATIONSHIP OF MEASURED EVAPOTRANSPIRATION TO SOLAR RADIATION IN WESTERN U.S.A.
- (b) Laboratory project, (joint project with Mr. M. E. Jensen, Northwest Branch.)
- (c) Dr. H. R. Haise, Agricultural Research Service, P. O. Box 758, Fort Collins, Colo.
- (d) Analytical and theoretical; basic and applied.
- (e) Measurements of evapotranspiration rates for one- to three-week periods made by USDA personnel during the past 35 years have been re-evaluated and selected data for field and orchard crops are being related to solar radiation and air temperature using an energy balance approach. Solar radiation data for 20 locations in the Western U.S.A. have been summarized and procedures developed for estimating radiation for specific periods. The resulting relationships can be used for estimating evapotranspiration for various crops.
- (f) Completed.
- (5207) VOLUMETRIC EROSION AND DEPOSITION ON A COMPLEX WATERSHED.
- (b) Laboratory project, cooperative with the Soil Conservation Service and Nebraska Agricultural Experiment Station.
- (c) Mr. Frank J. Dragoun, Hydraulic Engineer, ARS-SWC, Hastings, Nebraska.
- (d) Field investigations and office analysis; master's thesis study.
- (e) To develop a method of determining volumes of erosion and deposition within a watershed using topographic maps developed from aerial photographs, and to delineate the areas, determine the volumes and indicate the depths of erosion and deposition with time. It is expected that from this research a new method will evolve for use in conservation work.
- (5208) DEVELOPMENT OR CHANGES OF VEGETATION ON PERMANENT GRASS WATERSHEDS AS AFFECTED BY USE AND AS RELATED TO WATER YIELDS.
- (b) Laboratory project, cooperative with the Nebraska Agricultural Experiment Station.
- (c) Mr. Warren L. Rice, Engineering Technician, ARS-SWC, Hastings, Nebraska.
- (d) Field investigations--applied research; compilation and analysis of data.
- (e) Objectives of the research are: (1) To follow deterioration of vegetation when converting from meadow to pasture; (2) to follow development of vegetation on cropland seeded to native grasses; and (3) to follow changes in vegetative cover of a permanent pasture watershed. In all cases the effect on water yields will be determined. It is the purpose of this research to provide needed information on the effect of changes in pasture and meadow land use on runoff and water yields.
- (5566) LABORATORY STUDY OF DELTA DEVELOPMENT INDUCED BY FLOOD-WATER RETARDING AND SEDIMENT DETENTION STRUCTURES.
- (b) Laboratory investigations cooperative with the Colorado Agricultural Experiment Station.
- (c) Mr. R. H. Brooks, Agricultural Engineer, ARS-SWC, Fort Collins, Colorado.
- (d) Experimental investigations; basic and applied.
- (e) Purpose of project is: (1) To investigate the dynamic processes involved in delta (topset bed) development above floodwater or debris storage structures, and (2) to develop equations and graphical representations describing the delta development processes in terms of the variables involved.
- (g) Project initiated September, 1964. As yet, no data have been obtained.
- (5567) AUTOMATION OF SURFACE IRRIGATION SYSTEMS.
- (b) Laboratory and field investigations.
- (c) Dr. H. R. Haise, Research Investigations Leader, Water Management, P. O. Box 758, Fort Collins, Colorado

- (d) Laboratory and field project. Applied research. Development, design and operation of automated system.
 - (e) To develop labor-saving devices for surface application of irrigation water to farm fields for more efficient use of existing water supplies. Study involves development and testing of remote operation of a pneumatic valve (patents pending) capable of controlling water in open ditch and closed pipe systems.
 - (f) In early stages of development.
 - (g) Water has been successfully applied to irrigation fields by radio control of pneumatic valves at distances up to one mile or more. Further studies are to be initiated at five locations where automatic systems will be operated and tested on a total farm basis.
- (5568) THE EFFECT OF SLOPE WITHIN A WATERSHED ON WATER INTAKE AND RUNOFF FROM RAINFALL.
- (b) Laboratory project cooperative with Nebraska Agricultural Experiment Station.
 - (c) Mr. Norris P. Swanson, Agricultural Engineer, ARS-SWC, Lincoln, Nebraska.
 - (d) Field investigations; basic and applied.
 - (e) Purpose of the project is: (1) To measure and compare intake, runoff, and erosion from plots on slopes of approximately 3, 6, and 10 percent, located within small 4-acre watersheds using simulated rainfall; and (2) to construct runoff hydrographs using simulated rainfall data for comparison with hydrographs obtained from natural rainfall.
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- U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.
- NORTHWEST BRANCH, P. O. Box 1096, Boise, Idaho, Dr. J. S. Robins, Branch Chief.
- (3550) THE EFFECT OF SPRINKLER PATTERN VARIATION ON IRRIGATION EFFICIENCY.
- (b) Laboratory project.
 - (c) Mr. Claude H. Pair, Research Engineer (Irr.), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho.
 - (d) Experimental; applied research and design.
 - (e) To determine the effect of sprinkler pattern on field irrigation efficiency and develop a method for calculation of field water application efficiency for a sprinkler system from sprinkler pattern, wind velocity, humidity, temperature, irrigation period, and related factors. Another phase of this project is to test typical sprinkler heads for reproducibility of water distribution pattern.
 - (f) In completion stage.
 - (g) Tests conducted to date indicate that 90 percent of the water applied by the sprinklers to the plots could be accounted for in the catch cans and correction for evaporation using the Frost-Schwalen nomograph. Only 79 percent of the water could be accounted for by the soil sampling method when corrected for consumptive use of plants and evaporation from the sprinkler nozzle to the soil surface using the Frost-Schwalen nomograph. The losses not accounted for above are being investigated.
 - (h) "Making Use of Sprinkler Pattern Data," Claude H. Pair, Irrigation Engineering and Maintenance, Vol. XIII, No. 7, pp. 10-11, 26. Oct.-Dec. 1963.
- (3552) HYDRAULICS OF SURFACE IRRIGATION.
- (b) Laboratory project.
 - (c) Mr. James A. Bondurant, Agricultural Engineer, Agricultural Research Service, Route 1, Box 186, Kimberly, Idaho 83341.
- (d) Experimental; field investigation, basic research.
 - (e) To investigate the factors that influence the advance and recession of water in an irrigation border strip.
- (3553) DEVELOPMENT OF AUTOMATIC SURFACE IRRIGATION EQUIPMENT.
- (b) Laboratory-field project.
 - (c) Mr. Allan S. Humpherys, Agricultural Engineer, Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho.
 - (d) Experimental; design and development.
 - (e) To develop automatic and semi-automatic control structures for surface irrigation.
 - (g) Gates which will check the flow of water in a head ditch for a pre-determined period of time are being developed. These allow a field to be irrigated a portion at a time. Automatic and manual reset gates are being developed for both lined and unlined ditches. These are controlled by mechanical timers, electrically and with floats.
 - (h) "Mechanized Surface Irrigation." Colorado Rancher and Farmer, pp 18, 34, March 10, 1962.
"Mechanization of Surface Irrigation," Doane Agricultural Digest, Western Edition, V. 25, No. 10-7, May 16, 1962.
"Automation comes to Surface Irrigation," Western Farm Equipment V. 59, No. 6, pp 16-19, June 1962.
"Surface Irrigation Through Automatic Control," Underground Raindrops, V. 6, No. 2, Summer 1962.
"Hydraulic and Geometrical Relationships of Lay-Flat Irrigation Tubing," by A. S. Humpherys and C. W. Lauritzen, USDA Technical Bulletin No. 1309, October 1964.
- (4311) FLOOD HYDROGRAPHS BY ELECTRONIC ANALOG.
- (b) Laboratory project, cooperative with the University of Idaho.
 - (c) Mr. J. Marvin Rosa, Hydraulic Engineer, P. O. Box 414, Moscow, Idaho.
 - (d) Analytical, basic and applied.
 - (e) Further development and adaption of electronic analog methods in the solution of flood routing problems and the prediction of flood hydrographs from agricultural and foothill range watersheds of the northwest.
- (4312) WATER YIELD AS INFLUENCED BY WATERSHED CHARACTERISTICS.
- (b) Laboratory project, cooperative with the University of Idaho.
 - (c) Mr. J. Marvin Rosa, Hydraulic Engineer, P. O. Box 414, Moscow, Idaho.
 - (d) Analytical.
 - (e) Regional analysis of water yield as affected by climatic, topographic, geologic, soil, land use and other characteristics of rangeland watersheds in the Northwest.
- (4313) SNOWMELT HYDROGRAPHS AS INFLUENCED BY CLIMATIC FACTORS AND WATERSHED CHARACTERISTICS.
- (b) Laboratory project, cooperative with the University of Idaho.
 - (c) Mr. J. Marvin Rosa, Hydraulic Engineer, P. O. Box 414, Moscow, Idaho.
 - (d) Analytical, basic and applied.
 - (e) To develop improved methods for estimating daily hydrographs of streamflow from mountainous watersheds where the supply is from snowmelt and occasional rain.
- (4314) PRECIPITATION CHARACTERISTICS OF A NORTHERN SEMI-DESERT WATERSHED.
- (b) Laboratory project.
 - (c) Mr. Freeman M. Smith, Research Botanist, P. O. Box 2724, Boise, Idaho.
 - (d) Experimental, basic and applied.

- (e) The 93 square mile Reynolds Creek Experimental Watershed, Owyhee County Idaho, has recording raingages to a density in excess of one per square mile. From this network, methods for evaluating rainfall amounts and intensities for different areas are being developed. Seasonal distribution with respect to amounts, character, and areal extent of precipitation are being measured.
- (g) Topography greatly influences precipitation in Reynolds Valley. The regression equations for the relation of precipitation to elevation, computed for the east and west half of the watershed are parallel, but there is a five inch difference in the constant term in the equations. This is attributable to the position of the valley in relation to incoming storms. Precipitation is extremely variable in the semi-arid Northwest. To estimate mean precipitation in a stream basin in the mountainous Northwest similar to Reynolds Creek in relation of precipitation to elevation, topography, elevation, storm patterns and rainfall with 95 percent confidence of being + or - 1 inch would require approximately 55 rain gages.
- (4315) THE DESIGN OF SELF-PROPELLED SPRINKLER SYSTEMS.
- (b) Laboratory project.
- (c) Mr. Claude H. Pair, Research Engineer (Irr.), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho.
- (d) Experimental, applied research, design.
- (e) Determine water application patterns of self-propelled sprinkler systems. Determine the effect of wind on application patterns of self-propelled sprinkler laterals, and develop method of designing self-propelled sprinkler laterals from theoretical formulas.
- (f) In completion stage.
- (g) Patterns of individual sprinklers making up the self-propelled moving lateral have been determined and are to be put together to see how the synthetic pattern compares with the field pattern of the moving lateral.
- (4834) INFLUENCE OF PHOTO SCALE, VEGETATION, TOPOGRAPHY, AND SNOW CONDITIONS ON PHOTOGRAMMETRIC MEASUREMENT OF SNOW COVER.
- (b) Laboratory project.
- (c) Mr. Charles F. Cooper, School of Natural Resources, Univ. of Michigan, Ann Arbor, Michigan.
- (d) Experimental; basic and applied.
- (e) This project seeks to determine the feasibility of determining the quantity of snow stored in a snowpack on a selected area by photogrammetric techniques and evaluate the influence of topography and vegetation on the accumulation and melting of snow. The study of different photoscales on the precision of estimate is included in the project.
- (f) Completed.
- (g) Photogrammetry is a practical means of determining the volume of snow on an area or its depth at a point in relation to land form and solar radiation. Photogrammetric snow depths consistently exceed measured depths by 0.5 to 1.0 foot, but it is possible to eliminate this bias with improved ground controls. The calculated standard deviation of snow depths is 0.78 foot at a photo scale of 1/6000.
- (4835) LEAF AND CROWN AREA OF ARTEMESIA TRIDENTATA.
- (b) Laboratory project.
- (c) Mr. Freeman M. Smith, Botanist, P. O. Box 2724, Boise, Idaho.
- (d) Experimental; basic and applied research.
- (e) Develop methods of determining total leaf area for a given size-vigor classification of A. tridentata. Determine the capacity of these leaves to store precipitation, intercept precipitation and to transpire. Evaluate the effect of immediate vegetation structure on leaf area of individual plants. Since vegetation and soils on watersheds act as reservoirs which receive, store and discharge water, an understanding of their individual performance in these capacities is tantamount to an understanding of watershed hydrology.
- (f) Completed.
- (g) Leaf area of sagebrush is best determined by measuring leaf volume per plant and dividing by average leaf thickness. Crown area is best estimated by crown ellipse. Leaf weight accounts for 93 percent of the variance in leaf area.
- (4836) WATER BUDGET OF A UNIT SOURCE AREA.
- (b) Laboratory project.
- (c) Mr. Freeman M. Smith, Research Botanist, P. O. Box 2724, Boise, Idaho.
- (d) Experimental; basic and applied research.
- (e) Determine as fully as possible the fate of water falling on a small representative watershed throughout the year and estimate evaporation and transpiration from readily obtained instrumental and climatological data. Such a general understanding of the disposition of precipitation on an area is basic to an understanding of the effects of soils, geology, vegetation and climate.
- (4837) FACTORS AFFECTING SNOW ACCUMULATION AND MELT ON UNIT SOURCE AREAS.
- (b) Laboratory project.
- (c) Mr. Freeman M. Smith, Botanist, P. O. Box 2724, Boise, Idaho.
- (d) Experimental; basic and applied research.
- (e) Determine physical and meteorological factors contributing to non-uniformity of snow accumulation and melt in a shrub covered unit source area in the sagebrush zone of Owyhee County, Idaho. Any improvement in the quantity or timing of flow from snow fed streams by manipulation of vegetation or other practices requires a thorough understanding of the behavior of snow under these conditions. Such information must be derived from research.
- (4838) A STUDY OF SURFACE WATER DIVERSIONS AND RETURN FLOW IN REYNOLDS VALLEY.
- (b) Laboratory project.
- (c) Mr. Clifton W. Johnson, Hydraulic Engineer, P. O. Box 2724, Boise, Idaho.
- (d) Experimental; basic and applied research.
- (e) This investigation is designed to find the consumptive use of water by an upstream irrigated area as it affects downstream water supplies. All of the inflow to Reynolds Valley is measured as is the outflow and general ground water levels.
- (g) Preliminary data indicate about 50 percent of water diverted is retained on the land. Because of incomplete instrumentation, conclusive results are not yet available.
- (4839) GEOLOGIC CONTROL OF SUBSURFACE STORAGE AND FLOW CHARACTERISTICS OF BASALT TERRANE.
- (b) Laboratory project.
- (c) Mr. Gordon R. Stephenson, Geologist, P. O. Box 2724, Boise, Idaho.
- (d) Experimental; basic and applied research.
- (e) The purpose of this project is to evaluate the hydrologic effects of the basalts found on Reynolds Creek Experimental Watershed, Owyhee County, Idaho. The objective is approached by studying the water balance on a closed basaltic basin.
- (g) The basalts on Reynolds Creek are much less permeable than those on the Snake River plains.
- (4840) THE DEVELOPMENT OF A PORTABLE IRRIGATION SPRINKLER EVALUATION DEVICE.

- (b) Laboratory project. See project 4368, page 135.
 - (c) Mr. Claude H. Pair, Research Engineer (Irr.), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho.
 - (d) Experimental; applied research.
 - (e) To design a portable device that can be used in the design and evaluation of sprinkler irrigation systems. To determine procedures for the use of this device.
 - (g) This equipment has been used to measure the intake rate of soil for sprinkler design.
 - (h) "A Method for Measuring Water Intake Rate into Soil for Sprinkler Design," Rhys Tovey and Claude H. Pair. Proceedings 1963 Open Technical Conference, Sprinkler Irrigation Association, pp 109-118, 1963.
- (5209) DEVELOPMENT OF IRRIGATION WATER MEASURING DEVICES AND METHODS.
- (b) Laboratory and field project.
 - (c) Mr. A. R. Robinson, Director, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, (Twin Falls) Idaho 83341.
 - (d) Experimental design and development.
 - (e) To develop devices and methods for accurate measurement of flow of water.
 - (g) Improved devices will be developed to measure flow in pipes, channels and underground. Specifically, devices to be or being studied include: (1) Combination headgate and measurement structures, (2) improved measuring flumes, (3) runoff measuring structures for watersheds, (4) devices utilizing drag or deflection principles, and (5) dye diffusion techniques.
- (5569) IRRIGATION WATER MANAGEMENT ON SUGAR BEETS.
- (b) Laboratory project.
 - (c) Mr. Marvin E. Jensen, Investigations Leader (Water Management), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
 - (d) Experimental, applied research.
 - (e) Two moisture levels each with 3 nitrogen rates are irrigated for 3 time durations to simulate the upper, middle and lower parts of a field. The influence of these practices on yield, sugar percentage, nitrogen recovery, and deep percolation water losses will be evaluated.
- (5570) FACTORS AFFECTING FARM AND PROJECT IRRIGATION EFFICIENCIES.
- (b) Laboratory project.
 - (c) Mr. Marvin E. Jensen, Investigations Leader (Water Management), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
 - (d) Field investigation; applied research.
 - (e) Detailed measurement of the disposition of irrigation waters on selected farms will be made by the USBR and ARS to evaluate the factors affecting farm and project irrigation efficiencies.
- (5571) DESIGN OF RECIRCULATING IRRIGATION SYSTEMS.
- (b) Laboratory project.
 - (c) Mr. James A. Bondurant, Research Agricultural Engineer, Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
 - (d) Field investigation; applied research and design.
 - (e) This project will develop criteria for design of pumping systems to return irrigation runoff water to the distribution system. Possible amounts and rates of runoff waters will be determined, both theoretically and on a field basis. Size of system, (pump, sump, pipeline, etc.) as well as system operation are being investigated.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

SOUTHERN BRANCH, University of Georgia, Athens, Georgia, Dr. A. R. Bertrand, Branch Chief.

(3869) FLUVIAL MORPHOLOGY.

- (b) Laboratory project, cooperative with the Univ. of Miss. and Mississippi State Univ.
 - (c) Dr. Neil L. Coleman, Geologist, and Mr. Richard A. Stein, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
 - (d) A joint field and laboratory project - basic and applied research.
 - (e) Detailed field measurements are made on selected natural water courses and flood plains in the Yazoo River Basin and other selected locations in Mississippi to delineate the variables of stream geometry, bend and bank roughness factors, dune migration, and stream hydraulics in terms of sediment transport characteristics. Laboratory studies in both 100-foot and 50-foot long flumes are carried out to define significance of various factors under controlled conditions. Acquired data are studied for adherence to existing regime equations, tractive force concepts, resistance coefficients, and bed material transport formulae, and to develop new or improved concepts and relationships.
 - (f) Discontinued.
 - (g) The existence of a discontinuity in the stage-discharge relation under certain conditions in sand-bed streams has been established. Changes in channel conveyance efficiency, occasioned by changes in bed configuration have resulted in variances in water discharge of over 100 percent for given water stages. Variations in Manning's roughness coefficient from 0.015 to 0.035 during the course of a storm runoff event have occurred, and for a given water discharge on separate occasions the "n" value has been known to double. Similar variations in the Darcy-Weisbach coefficient have been noted. Froude numbers for floods over plane beds or antidunes in the field are less than Froude numbers computed from comparable flow conditions in the laboratory flumes; this difference in Froude numbers is believed to be partly a function of depth.
 - (h) "Observations of Resistance Coefficients in a Natural Channel," by Neil L. Coleman. Publication No. 59, I.A.S.H. Commission on Land Erosion, pp. 336-352, 1962.
- (3870) AGGRADATION AND DEGRADATION AS RELATED TO CHANNEL STRUCTURES.
- (b) Laboratory project, cooperative with the Univ. of Miss. and Miss. State University.
 - (c) Mr. Joe C. Willis, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi, and Mr. Paul Yates, Hydraulic Engineer, P. O. Box 33, Watkinsville, Georgia.
 - (d) Field and laboratory investigations; basic and applied research.
 - (e) It is necessary for proper planning and design of agricultural watershed conservation work to have knowledge of the extent of aggradation or degradation that is likely to occur with placement of structures in alluvial channels. Studies of deposition and scour as related to actual structures at various locations in Mississippi, Georgia, Wisconsin and other selected locations to provide the needed field data are underway to develop procedures and criteria useful in predicting channel adjustments with structural installations and accompanying changes in sediment transport and flow pattern.
 - (g) Channel surveys show a slow rate of degradation of the streambed of Barber Creek, Georgia, where the control of flood flows

by flood water detention structure is greatest. Here the watershed is about 95 percent controlled. The degree of channel scour and channel erosion rates are being determined in connection with several structural installations in Mississippi. Case histories of over 70 gully control structures in Wisconsin have been established. Laboratory studies of degradation have been started. The rates of degradation of laboratory sand-bed channels following suspension of sand feed to the channel were measured. Three different sands were used.

(3871) LABORATORY STUDIES OF SEDIMENT TRANSPORT.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Mr. Richard A. Stein, Hydraulic Engineer, USDA Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Experimental; basic and applied research.
- (e) Laboratory flume experiments are conducted to determine bed material transport, bed material qualities, and stream hydraulics.
- (g) In laboratory tests with a 400-micron median-diameter sand and depths of flow ranging between 0.4 ft. and 1.1 ft. the variable $\frac{V - 1.1}{1.4 (y + 1.0)}$ is related to the type of bed form, the mean dune height, and the Darcy-Weisbach friction factor rather well. Total load and bed load was determined by mean velocity when moving dunes were present on the bed. When mean velocity was larger than the value producing minimum bed friction factor, total load was a function only of mean bed shear stress. A comparison of transport rates with those calculated by certain formulas, showed Schoklitsch's to be preferable because of applicability and ease of computation.

(4305) TRAP EFFICIENCY OF RETARDING-TYPE RESERVOIRS.

- (b) Laboratory project, cooperative with the Soil Conservation Service and the U. S. Geological Survey.
- (c) Mr. D. A. Parsons, Director, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Theoretical and field investigations, and office analyses.
- (e) The trap efficiency of a reservoir is a measure of the effectiveness of the structure in retaining incoming sediment. Structures need to be designed and built with different degrees of trap efficiency, and information is needed so that the influencing parameters can be adjusted to provide the desired trap efficiency. In this study we are endeavoring to (1) collect and study data from retarding-type reservoirs in order to determine those factors that influence trap efficiency, and (2) derive and test methods for predicting the trap efficiency of retarding-type reservoirs.

(4316) HYDRAULICS OF CHANNELS RELATIVE TO CHANNEL STABILITY.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Mr. D. A. Parsons, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Experimental, field investigations, applied and basic research.
- (e) The determination of flood flow qualities in selected reaches of Pigeon Roost Creek Mississippi, and other streams in studies of the resistance to erosion of streambank and bed materials, and streambank vegetation. Measurements of the boundary shear stresses in curved channels as affected by bend radius, bed angle, and Froude number.

(4317) PRINCIPLES OF STABLE CHANNELS IN COHESIVE MATERIALS.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Dr. Earl H. Grissinger, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Experimental, applied and basic research.
- (e) To study the properties of cohesive materials that determine their stability to flowing water. Rates of erosion are measured by subjecting remolded materials to a constant erosive flow of water. Objectives are: (1) to determine the reasons for the resisting ability of soil and stream-bank materials to erosion by flowing water; (2) to determine the kinds of tests needed to measure the resistance; and (3) obtain the quantitative values of the resistance for natural and synthetic materials. The stability of cohesive material was found to be dependent upon the type, amount, and orientation of the clay minerals; the bulk density, antecedent moisture, and wet-age time of the sample; and the temperature of the eroding water. In general, stability increases with increasing clay mineral content and with increasing density. Stability was greater for the 2:1 type clay mixture than for the 1:1 type.

(4318) METHODS OF CHANNEL STABILIZATION.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Mr. D. A. Parsons, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Experimental, field investigations, applied and basic research.
- (e) Includes: (1) Determination of the speeds of motion and the requisite conditions for beginning of motion of solid particles in fluid flow for various flow, particle quality, and boundary conditions in a laboratory study; (2) field investigations on Pigeon Roost Creek, Mississippi, and other streams of the resisting abilities of bank and bed materials and bank vegetation as determined by measured flood experiences (this study is associated with the one on channel hydraulics); and (3) laboratory and field study of the behavior of non-cohesive sands and silts in a stream channel bank for the conditions of lateral seepage flow to the stream.

(4319) SEDIMENT YIELDS AND CORRELATION WITH WATERSHED CHARACTERISTICS.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Messrs. Farris E. Dendy and Andrew J. Bowie, Agricultural Engineers, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Field investigation, applied research.
- (e) Analyses of hydrologic, hydraulic, land use, soils, and physiographic characteristics of agricultural watersheds (varying in size from a fraction of an acre to 100 sq. mi.) are made to establish relationships with sediment transport rates, amounts, and delivery ratios. Establishment of methodology for determining long-time average annual sediment yields from fragmental field data, correlation of characteristics of the basic runoff-sediment relation (sediment rating curve) with affecting hydraulic and hydrologic parameters, and evaluation of the role of large storms as sediment contributors, are all basic objectives that will lead to better sediment yield prediction procedures. Data from Pigeon Roost Creek Basin, Miss., indicates that sediment yields are highly correlated with direct runoff. Variations in unit direct runoff (and therefore unit sediment) yields between watersheds of the basin are marked. They have to some extent been correlated with basin physiography.

and land use. There are significant channel transmission losses in streams of the basin.

(4320) SEDIMENT ORIGIN AND ROUTING.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Dr. L. L. McDowell, Soil Scientist, Sedimentation Lab., P. O. Box 30, Oxford, Mississippi.
- (d) Experimental, basic research.
- (e) Runoff and sediment production are measured from a small gully typical of the Yazoo-Tallahatchie Watershed. Sediment produced from this gully will be related to gully area, thereby providing information on the rate of gully erosion. When applicable, comparisons will be made between the estimated sediment discharge utilizing radio-active tracer sand, and the measured sediment discharge.
- (g) Runoff and sediment measuring equipment have been installed. A detailed topographic survey has been made of the gully area. Surveys will be made periodically to observe changes in gully shape.

(4321) RESERVOIR SEDIMENTATION.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Dr. J. Roger McHenry, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Experimental and field investigation for basic research and developmental work.
- (e) To relate sediment accumulation in reservoirs to sediment yields, runoff, and physical parameters of the watersheds. The nature of the sediment, its origin, mineralogy, chemistry, and biology are studied in relation to distribution and deposition within the reservoir. Nuclear methods are used where applicable.
- (g) A number of reservoirs have been periodically surveyed for sediment accumulation. Nuclear means of determining in situ densities have been employed.
- (h) "A Two-Probe Nuclear Device for Determining the Density of Sediments," by J. Roger McHenry, IASH Publication No. 65, 189-202, 1963.

(4322) DEVELOPMENT OF METHODS FOR UTILIZING RADIOACTIVE ISOTOPES AND RADIOACTIVE MATERIALS FOR SEDIMENTATION AND HYDROLOGY RESEARCH.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Dr. J. Roger McHenry, Soil Scientist and Dr. L. L. McDowell, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Experimental basic research.
- (e) To devise, develop, and utilize procedures for "tagging" sediment particles with radioisotopes and identifying same in the laboratory and in the field. Results are to be used in predicting sediment production, transport and deposition.
- (g) A satisfactory method has been developed for "tagging" quartz particles with scandium-46, silver-110, cerium-144, and antimony-124.

(4323) SEDIMENT PRODUCTION AND CONTROL PRACTICES ON HIGHWAY CUTS AND FILLS.

- (b) Laboratory project, in cooperation with Georgia State Highway Dept., Soil Conservation Service USDA, the University of Georgia College of Agriculture Experiment Stations, and Bartow County, Georgia.
- (c) Mr. E. G. Diseker, Agricultural Engineer, P. O. Box 124, Cartersville, Georgia.
- (d) Experimental, field; applied.

- (e) Runoff and soil losses are measured from one pair of bare roadbank plots and two pairs of plots vegetated in early 1963 (approximately 1:1, 2:1, and 3:1) on Cecil Clay subsoil using six H-flumes and Coshoc-ton vane samplers. On the two pairs of plots that were vegetated annual soil loss was approximately 13 times greater than before they were vegetated. Metal hub stakes are used as an adjunct in determining bank erosion, and for measuring deposition or scour from the flow channels. Over 30 different plants have been tested on 850 roadbank plots for erosion control.

- (g) Bare bank losses have varied from 25 to 400 tons per year per acre for the past 5 years depending on the rainfall, frost action, bank aspect and slope. Bank aspect and frost action have been major factors in the erosion process. Banks facing northwest have lost, on an average, 2.2 times as much soil as those facing southeast. Plants which have proved satisfactory for erosion control are fescue, common Bermudagrass, lovegrass, broomsedge, Pensacola and Wilmington Bahiagrasses, crownvetch, sericea lespedeza, honeysuckle and kudzu. For the establishment of satisfactory cover on slopes 2:1 and steeper, mulches were necessary particularly for the slowly developing plants such as crownvetch and Bahiagrasses. For maintenance of most plants, especially the grasses, a timely application of fertilizer is necessary. Previously outlined procedures to determine fertility requirements for maintaining vegetation on roadside areas in the Piedmont Uplands of Georgia were put into practice in the fall of 1962. Studies to determine rates and amounts of sediment delivery for selected storms at monthly intervals and annual production and delivery from bare road banks in relation to (1) rainfall intensity (2) antecedent moisture and temperature conditions and (3) face slope length with different aspects on Cecil type soils will begin in the spring of 1963. A study was initiated in the spring of 1963 to determine sediment productions and delivery rates from fully developed, mature stands of five different representative plant species.

- (h) "Native Plants for Highway Erosion Control," by E. C. Richardson & E. G. Diseker. Abst., Proc. Assoc. Agr. Workers, 61st Annual Convention, Atlanta, Ga., Feb. 1964.

(4324) UTILIZATION OF TRITIUM IN WATERSHED RESEARCH.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Dr. J. Roger McHenry, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Experimental basic research and development.
- (e) To devise, develop, test and apply tracer techniques using tritium and other radioisotopes in support of studies of soil moisture and groundwater movement.
- (f) Inactive.
- (g) Methods of high efficiency have been developed using a liquid scintillation counter. Laboratory studies have shown the precision and accuracy of the methods are adequate. Some field tests have been conducted. Results have not been conclusive. Tests designed to date water in limestone aquifers have not been completed.

(4325) RUNOFF FROM AGRICULTURAL WATERSHEDS.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Mr. A. J. Bowie, Hydraulic Engineer, USDA Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Field investigations; basic and applied

- research.
- (e) To develop procedures for predicting flood runoff, water yield and hydrograph characteristics for ungaged upstream watersheds. Runoff and precipitation are observed for the 117 square-mile Pigeon Roost Creek Watershed in Northern Mississippi including 11 sub-watersheds, and for four unit-source watersheds under 4 acres in size. These data, accumulated over the past four years, are being processed by computer and analyzed to develop synthetic unit hydrographs by incorporating antecedent soil moisture and watershed factors. The predicted hydrographs will be used to establish flow-duration curves.
 - (h) "Computation of Direct Runoff Amounts from Storm Rainfall," by W. R. Hamon, International Association of Scientific Hydrology, Publication No. 63, pp. 52-62, 1963.
- (4326) SUBSURFACE HYDROLOGY.
- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
 - (c) Mr. F. E. Dendy, Agricultural Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
 - (d) Experimental and field investigations; basic and applied research.
 - (e) To study the hydraulic characteristics of geologic strata and develop methods of predicting ground water accretion and movement; subsurface and ground water contribution to streamflow from a knowledge of geology, soils, topography, climate, land use and treatment of agricultural watersheds; and to evaluate hydrogeologic factors governing transmission gains and losses in stream channels. A portable drilling rig is utilized to obtain geologic samples, establish ground water observation wells, and conduct permeability field tests.
 - (g) Maps showing structural and stratigraphic characteristics and groundwater contours of the Pigeon Roost Creek watershed have been prepared. Estimates have been made of ground-water storage and outflow from the watershed.
 - (h) "Permeability Measurements with Small Well Points," by F. E. Dendy and L. E. Asmussen, Transactions ASAE, Vol. 6, No. 4, pp. 297-300, 303, 1963.
- (4327) MOISTURE REGIMES OF AGRICULTURAL WATERSHEDS.
- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
 - (c) Mr. John Kozachyn, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
 - (d) Field investigation; applied research.
 - (e) To provide soil moisture data for the development of prediction techniques for runoff and sediment production and to relate the moisture regimes of agricultural watersheds to soil, climate and vegetative parameters. Field observations of soil moisture to depths of 10 and 20 feet are obtained by the neutron probe method for different cover, slope, and soil complexes.
 - (g) The superiority of the neutron probe procedure over other available methods was established from laboratory and field tests. A method of installing access tubes has been perfected.
 - (h) "A Method for Installation of Access Tubes and the Development of Field Equipment for Measuring Soil Moisture by Neutron Scatter," John Kozachyn and J. Roger McHenry, Agronomy Journal, Vol. 56:443-444, 1964.
- (4328) RELATION OF CLIMATE AND SOIL MOISTURE LEVELS TO PLANT GROWTH AND WATER USE.
- (b) Laboratory project, cooperating with the Central and Southern Florida Flood Control District and the Florida Agricultural Experiment Station.
- (c) Mr. E. H. Stewart, Soil Scientist, P. O. Box 9087, Fort Lauderdale, Florida.
 - (d) Laboratory and field investigations, both basic and applied for evaluating measured environmental conditions.
 - (e) Laboratory and field procedures are employed to determine moisture intake, retention and transmission characteristics of mineral and organic soils. Controlled water table studies in non-weighing lysimeters are conducted to determine evapotranspiration, crop growth, and soil physical properties as influenced by various water table depths. Field and plot studies in organic soils are conducted to determine soil subsidence.
 - (g) Average daily evapotranspiration of Bermudagrass ranged from 0.07 inch for the three winter months to 0.14 inch for the period April through August. During an extended rain-free period of six weeks, evapotranspiration was about 23 percent less for the 36-inch water table than for the 12-inch water table. Good correlation existed between radiant energy, measured at the earth's surface, and measured potential evapotranspiration of Bermudagrass and standard pan evaporation. Surveys over established subsidence lines on the organic soils of the Florida Everglades in 1963 show that the average rate of subsidence since 1912 has been 0.096 foot per year. Seepage through the rock strata underlying a peaty-muck soil at the Everglades Experiment Station appears to be an important factor affecting water table control.
- (4329) HYDROLOGIC RESEARCH ON SMALL AGRICULTURAL WATERSHEDS IN CENTRAL AND SOUTHERN FLORIDA.
- (b) Laboratory project, cooperating with the Central and Southern Florida Flood Control District and The Florida Agricultural Experiment Station.
 - (c) Mr. E. H. Stewart, Soil Scientist, Attention: W. H. Speir, Engineering Technician, P. O. Box 9087, Fort Lauderdale, Fla.
 - (d) Experimental, field investigations; basic and applied research.
 - (e) To collect, analyze, and correlate basic hydrologic data on agricultural watersheds ranging in size from 4,000 to 63,000 acres in the Coastal Plain of Florida. To determine the influence of climate, topography, soils, geology, and land use on the rate and volume of runoff and to evaluate the water balance. To devise methods of interpreting watershed characteristics as similitudes related to physiography of other areas.
 - (g) For an unimproved 98.7-sq. mile watershed the maximum daily discharge (Oct. 1956) was 2.28 inches-over-area with an instantaneous peak rate of 70 c.f.s./sq. mile; and for the 15.7-sq. mile upper sub-basin the respective rates were 3.14 inches and 158 c.f.s./sq. mile. For an improved 78 square mile watershed the maximum daily discharge (Sept. 1960) was 2.37 inches-over-area with an instantaneous peak rate of 66 c.f.s./sq. mile. The ratio of runoff to rainfall averaged 0.43 for the artesian-irrigated 78 sq. mile watershed until 1959. Increased use of artesian irrigation water increased this ratio to 0.55 after 1959. For the 98.7-sq. mile unimproved watershed this ratio has averaged 0.32 and for the 15.7-sq. mile sub-basin, 0.27 since 1955. Total storm yield varied inversely with area on the unimproved watersheds. For the 98.7 sq. mile watershed base flow has averaged 84%, interflow 8%, and overland flow 8% of total streamflow. For the 78-sq. mile watershed these flow components have averaged 75%, 19%, and 6% respectively. For the 15.7 sq. mile watershed they averaged 40%, 32%, and 28%. Data from three watersheds were analyzed to determine the suitability of the Cypress Creek Formula ($Q = CM^{5/6}$) for drainage design and to develop the relation of C to probable flood recurrence frequency. In this formula, Q is the maximum runoff rate for 24 hours in c.f.s.; M is drainage area

- in square miles, and C is a coefficient. The formula appeared to be suitable for estimating required drainage capacity in sandy flatwoods areas of the Southeast. The relation: $C = 16.39 + 14.75 \times \text{rainfall excess}$ provided a guide for selecting C values based on rainfall excess. The probability of occurrence of excess rainfall can be related to 24-hour storm rainfall by subtracting the local soil storage potential.
- (h) "Using the Cypress Creek Formula to Estimate Runoff Rates in the Southern Coastal Plains and Adjacent Flatwoods Land Resource Areas," by John C. Stephens and W. C. Mills. U. S. Dept. Agr. ARS 41-95, December 1964.
- (4330) RUNOFF AND EROSION CHARACTERIZATION OF BROWN LOAM SOILS.
- (b) Laboratory project.
- (c) Mr. Cade W. Carter, North Mississippi Branch Experiment Station, Holly Springs, Miss.
- (d) Experimental, field; basic and applied.
- (e) Rates and amounts of runoff and soil losses from small plots are measured. The plots range in size from 1/45 acre to 4 acres. The slopes of the smaller areas are 2-1/2 percent, 5 percent, and 10 percent. Land use varies from fallow and cultivated to pasture, with good and poor management conditions for the cultivated and pastured areas.
- (g) Both water and soil losses are excessive on bare land, and are reduced as the degree of ground cover is increased.
- (4331) HYDRAULICS OF FARM WATER CONTROL IN THE SOUTHERN PIEDMONT.
- (b) Laboratory project in cooperation with the University of Georgia, College of Agriculture Experiment Stations.
- (c) Mr. W. Campbell Little, Research Agricultural Engineer, Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Ga.
- (d) Experimental laboratory; basic and applied.
- (e) Basic research on the mechanics of erosion and hydraulics of flow in individual crop rows and in terraced channels will be developed for both terrace systems and individual row systems for the different soils of the Piedmont.
- (g) Initial studies are underway.
- (4332) SURFACE DRAINAGE -- ROW LENGTHS AND GRADES FOR REMOVAL AND APPLICATION OF SURFACE WATER ON FORMED AGRICULTURAL LAND OF THE MISSISSIPPI DELTA.
- (b) Laboratory project in cooperation with the Louisiana Agricultural Experiment Station.
- (c) Mr. Irwin L. Saveson, Project Administrator, Agricultural Engineering Building, Louisiana, P. O. Drawer 8817, University Station.
- (d) Experimental; basic and applied research.
- (e) Approximately 80 acres of land have been formed with four different slopes, in two replications, of 0.1', 1.15', 0.2', and 0.25'. For each slope class, row lengths of 500', 700', 900', and 1,100' will be used to determine the maximum row length for formed land as related to slope. Runoff, time-of-concentration, infiltration, soil temperature, and soil moisture data will be gathered and correlated with rainfall, wind humidity, and sunshine radiation. Future studies are contemplated to evaluate flow characteristics of surface water in furrows on agricultural land. This information will be used to develop a furrow cross-section with the best hydraulic characteristics.
- (g) An evaporation recorder has been developed. Data have been collected and are being analyzed for years 1963 and 1964.
- (4333) RUNOFF AND EROSION STUDIES FOR THE SOUTHERN PIEDMONT.
- (b) Laboratory project in cooperation with the University of Georgia, College of Agriculture Experiment Stations.
- (c) Mr. A. P. Barnett, Research Agricultural Engineer, Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Ga.
- (d) Experimental field investigations, development and applied.
- (e) The purpose of these studies is to determine the interrelations of climate, soil, topography, cover, management, row direction, runoff, soil movement and loss from Southern Piedmont soils. The work is conducted on fractional acre field plots under both natural and simulated rainfall. The natural rainfall plot study includes six cover, two row direction and three slope steepness treatments on a total of 42 plots. Total amounts of runoff and soil loss are measured for individual rainstorms. Meteorological data are also secured. The rainfall simulator designed to apply rain at 5, 2-1/2 and 1-1/4 inches per hour simultaneously to three adjacent plots is used to secure runoff, soil loss, and pesticide loss data from specific soil, slope, crop, and management complexes through the application of designed storms. These data are used to evaluate their runoff and erosion control effectiveness.
- (h) "Thunderstorms - the Principal Cause of Erosion in the Piedmont," by A. P. Barnett, J. S. Rogers, and Carlisle Cobb, Jr., Georgia Agricultural Research, Vol. 1, No. 4, Spring 1960.
- "Erosion on Piedmont Soil," by A. P. Barnett and B. H. Hendrickson, Soil Conservation, Vol. 26, No. 2, September 1960.
- "Man-made Rainstorms - A New Tool for Erosion Research," by A. P. Barnett, J. S. Rogers, and Carlisle Cobb, Jr., Georgia Agricultural Research, Vol. 2, No. 4, Spring 1960.
- "An Evaluation of Factors Affecting Runoff and Soil Loss From Simulated Rainfall," by J. S. Rogers, A. P. Barnett, and Carlisle Cobb, Jr., Agr. Engr. Jour., Vol. 7, No. 4, 1964.
- "Construction and Operation of a 16-unit Rainulator," by L. F. Hermsmeier, L. D. Meyer, A. P. Barnett, and R. A. Young, ARS 41-62, March 1963.
- "Conservation Methods for Soils of the Southern Piedmont," by B. H. Hendrickson, A. P. Barnett, and O. W. Beale, USDA Agricultural Information Bulletin No. 269, May 1963.
- (4334) RUNOFF AND EROSION STUDIES FOR SOUTHERN COASTAL PLAINS SOILS.
- (b) Laboratory project in cooperation with the Georgia Agricultural Experiment Stations.
- (c) Mr. John R. Carreker, Research Investigations Leader, P. O. Box 1309, Athens, Georgia.
- (d) Field investigations; applied, for design.
- (e) The purpose of these studies is to determine interrelations of climate, soil, land cover, runoff and soil loss for Southern Coastal Plain soils. The work is conducted on 18 field plots, 1/20 acre in size, under natural rainfall. There are four cover treatments. Total amount of runoff and soil loss are measured for individual storms. Meteorological data are also secured.
- (g) Grass-based rotations and continuous corn have been evaluated, showing protective effects of perennial grass sods and of annual crop residues.
- (4841) SURFACE WATER STORAGE AND SUPPLY ON FARMS IN THE COASTAL PLAINS.
- (b) Laboratory project in cooperation with the Georgia Agricultural Experiment Stations and Soil Conservation Service, USDA, in Georgia.
- (c) Mr. John R. Carreker, Research Investigations

- Leader, P. O. Box 1309, Athens, Georgia.
- (d) Field investigation; applied for design and development.
 - (e) Purpose of the studies is to determine pond storage efficiency under various soil and topographic conditions as affected by watershed yield, pond surface evaporation, seepage into and out of the impoundment, farm use of storage, and related factors. Initial study to be on one rather typical farm pond in the coastal plain, with anticipation of extending the work to other ponds.
 - (g) Study currently in progress.
- (4842) SHALLOW WELLS AND IRRIGATION PITS FOR IRRIGATION AND OTHER FARM WATER SUPPLY IN THE COASTAL PLAINS.
- (b) Laboratory project in cooperation with the Georgia Agricultural Experiment Stations and Soil Conservation Service, USDA, in Georgia.
 - (c) Mr. John R. Carreker, Research Investigations Leader, P. O. Box 1309, Athens, Georgia.
 - (d) Field investigation; applied, for design and development.
 - (e) The purpose of the studies is to develop criteria by which engineers and soil scientists can classify sites for irrigation pits, shallow wells, or other access to shallow ground water aquifers in the coastal plains on the basis of topography and soils. Initial study is concerned with excavated irrigation pits, their adequacy of supply, the relation of recharge to rainfall and soils, and other related influences. Investigations now involve 3 pits, each under somewhat different soil and topographic situations.
 - (g) Study currently in progress.
- (4843) AN EFFICIENT DRAINAGE SYSTEM FOR SUGARCANE LAND.
- (b) Laboratory project in cooperation with the Louisiana Agricultural Experiment Station.
 - (c) Mr. Irwin L. Saveson, Project Administrator, Agricultural Engineering Building, Louisiana State University, Baton Rouge, Louisiana, P. O. Drawer 8817, University Station.
 - (d) Experimental applied research.
 - (e) The present conventional system of sugarcane land requires considerable land occupied by ditches and is costly to maintain. Experimental work is underway to develop a more efficient drainage system which will consume less land and be more economical to maintain. This is an adaptation of the cotton drainage system to sugarcane.
 - (g) This system reduces the amount of land in ditches from 4 to 7 percent with a \$5.22 per acre per annum savings in cost of maintenance.
 - (h) "An Efficient Drainage System for Sugarcane Land" by I. L. Saveson, USDA, ARS 41-72, March 1964.
- (5210) RADIOCARBON DATING OF SEDIMENTS.
- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
 - (c) Dr. L. L. McDowell, Soil Scientist (Chemistry), Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
 - (d) Laboratory and field investigations; basic research.
 - (e) To establish and maintain a radio-carbon dating laboratory meeting the requirements of sedimentation research. The program is used to supplement geomorphological investigations by providing information on (1) the age of sediments, e. g., buried soils and geologic horizons, and (2) the past rates of sediment aggradation and degradation.
 - (g) The carbon in samples to be dated is processed to benzene ($C_6^{14}H_6$) and the number of beta disintegrations arising from the natural C^{14} is determined by liquid scintillation spectrometry. The necessary equipment for synthesis of benzene has been built and tested for operation. The liquid scintillation spectrometer has been modified and stabilized for radio-carbon. The overall program has been standardized and calibrated using contemporary carbon standards (NBS) and inter-laboratory "check" samples from other dating laboratories. A few unknown samples have been dated; additional samples are now being processed.
- (h) "Radiocarbon Dating by Liquid Scintillation Spectrometry: The Synthesis of Benzene ($C_6^{14}H_6$)" by L. L. McDowell and M. E. Ryan, ARS 41-88, 1964.
- (5572) CHANNEL BEHAVIOR FOLLOWING CHANNEL DREDGING.
- (b) Laboratory project of USDA Sedimentation Laboratory, Oxford, Mississippi in cooperation with the Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Georgia, and the Univ. of Georgia, College of Agriculture Experiment Stations.
 - (c) Mr. Paul Yates, Research Hydraulic Engineer, Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Georgia.
 - (d) Experimental field investigations; basic research.
 - (e) Basic research to determine the effects of stream channel dredging and realignment on channel geometry, flow velocities, sediment transport, scour and deposition, and retardance factors.
- (5573) INFLUENCE OF FLOOD-RETARDING AND SEDIMENT DETENTION STRUCTURES ON CHANNEL REGIMES.
- (b) Laboratory project of USDA Sedimentation Laboratory, Oxford, Mississippi in cooperation with the Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Georgia, and the Univ. of Georgia, College of Agriculture Experiment Stations.
 - (c) Mr. Paul Yates, Research Hydraulic Engineer, Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Georgia.
 - (d) Experimental field investigations; basic and applied.
 - (e) Basic research to study stream channel adjustments that are induced by changes in water- and sediment-discharge characteristics, resulting from imposed channel alterations, dams, and other modifying installations. Also to develop procedures for predetermining channel changes likely to occur with structural installations and channel modifications.
- (5574) A MODEL STUDY OF THE FORCES EXERTED ON A PARTICLE ON A STREAM BED.
- (b) Laboratory project cooperative with the Univ. of Miss. and Miss. State Univ.
 - (c) Dr. Neil L. Coleman, Geologist, U. S. Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
 - (d) Experimental project; basic research.
 - (e) An enlarged Reynolds Model of a section of stream bed has been constructed in a water tunnel. Transducers for measuring the force exerted on an exposed individual particle on the model bed are being developed. Attempts will be made to determine whether the force applied to the particle by the flow has lift and yaw components as well as a drag component. If the study is successful, the data obtained will be represented as plots of lift, drag, and yaw coefficients against Reynolds number. This information could then be used, with certain limitations, to predict the forces to be expected under various flow conditions on particulate beds of material ranging in size from that of sand grains to that of rip-rap stones.
 - (g) The development of transducers is progressing.

(5575) A STUDY OF BED FORMS IN SAND BED CHANNELS.

- (b) Laboratory and field project, cooperative with the Univ. of Mississippi and Mississippi State University.
- (c) Mr. Richard A. Stein, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Basic and applied research.
- (e) Relate the median and the standard deviation of dune height, dune propagation speed, water depths over dune crest, and water surface slopes to mean velocity and depth of flow. Define the bed material and hydraulic conditions that are related to types and size of bed configurations.
- (g) The parameter $\frac{V - 1.1}{1.75Y + 1.25}$ appears to describe the median values of the dune properties studied. The standard deviations of these dune properties appeared to be independent of mean velocity and depth except for the depth of water over the dune crest, which increased with depth.

(5576) A STUDY OF BOUNDARY IRREGULARITY IN A CHANNEL WITH A SAND BED.

- (b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
- (c) Dr. Neil L. Coleman, Geologist, U. S. Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi.
- (d) Experimental investigation, basic research.
- (e) Flows with various bed regimes (dunes, antidunes, or other) were established in a laboratory flume. An echo-sounding instrument called The Dual Channel Stream Monitor was used to take detailed bed and water surface profiles over a 50-foot reach in the flume. The profiles are now being analyzed by means of a computer program that yields the mean depth of each experimental flow, the standard deviation about the mean depth, and a depth autocorrelation function for each flow. The autocorrelation function can be integrated to yield a length which may be considered a wave length of the boundary irregularities. The depth standard deviation is an expression of the amplitude of the irregularities. The purpose of the study is to determine if these length scales will adequately portray the geometry in studies of bed forms, the migrations and the influences on open channel flow resistance.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

SOUTHERN PLAINS BRANCH, ARS-USDA, Bushland, Texas, Dr. J. R. Johnston, Branch Chief.

(3879) CHARACTERIZATION OF THE "HOT SPOT" PROBLEM IN THE LOWER RIO GRANDE VALLEY OF TEXAS.

- (b) Laboratory project.
- (c) Mr. Ronald R. Allen, Agricultural Engineer, P. O. Box 267, Weslaco, Texas.
- (d) Experimental and field investigation - applied research.
- (e) The purpose of the study is to determine the extent of salinity problems; characterize and correlate the water table, soil, topographic and related measurable factors associated with salinity problems in the area.
- (f) Completed; manuscript for publication in review stage.
- (g) Extensive water table observations show a fluctuating seasonally high saline water table beneath the area. The water table and ground surfaces slope approximately one foot per mile to the northeast in the general direction of the Gulf Coast.

(3880) THE MICRODYNAMICS OF UNSATURATED MOISTURE

FLOW.

- (b) Laboratory project.
- (c) Dr. Craig L. Wiegand, Soil Scientist, P. O. Box 267, Weslaco, Texas.
- (d) Experimental, basic research.
- (e) The objectives are to obtain evidence on the generality of the parabolic moisture distribution with respect to the interface of extraction and to interpret unsaturated moisture flow in terms of molecular level mechanisms of flow. The experimental technique is that of inducing moisture flow by various techniques at a series of temperatures and measuring the flow rate. The Arrhenius equation is applied to the data and an activation energy calculated. The activation energy is then interpreted in terms of energy barriers to molecular level flow mechanisms. The soil columns are sampled at the end of the runs to determine the moisture distribution with respect to the interface of extraction.
- (g) The results to date indicate that the resulting moisture distribution is a function of peculiarities of the microdynamic flow processes involved and independent of the method of extraction.

(3881) FACTORS AFFECTING THE EVAPORATION OF FREE WATER.

- (b) Laboratory project.
- (c) Dr. Craig L. Wiegand, Soil Scientist, P. O. Box 267, Weslaco, Texas.
- (d) Experimental, basic research.
- (e) The evaporation of free water is being studied under controlled conditions to: (1) Obtain quantitative information on the rate of evaporation of free water under controlled atmospheric conditions; (2) measure the rate of evaporation of water as a function of water temperature; and (3) correlate the rate of evaporation with (a) the saturation deficit of the atmosphere, and (b) the fugacity of the water molecules. Evaporation is being measured under all combinations of 10, 20, 30, and 40 degrees C water temperature; 10, 20, 30, and 40 degrees C air temperature; and 30, 50, 70, and 90% relative humidity. Water temperature is controlled to plus or minus .1 degrees C, ambient temperature to plus or minus 1.0 degrees C, and relative humidity to plus or minus 3%.
- (f) Completed.
- (g) Water loss (evaporation) and gain (condensation) have been studied as a function of water surface temperature, ambient humidity, and ambient temperature. Data taking has been completed and statistical analyses have been made. The equation, $Y + .00229 + .03154 (p_0 - p) + .000061 (p_0 - p)^2$ wherein Y is the estimated evaporation or condensation in cm./day, p_0 is the vapor pressure of water, and p is the vapor pressure of air accounts for 99.4% of the variation in evaporation and condensation rate. It fits the data very well over the entire range 1.65 cm./day condensation to 4.9 cm./day evaporation. A second regression analysis in which relative humidity of the air (R.H.), ambient temperature (T_a), and water temperature (T_w) were the independent variables explained 89.7% of the variation. This equation is not recommended for predictive purposes, however, because it predicts too low evaporation rates in the upper and lower ranges, and too high evaporation in the midrange. A reduction in regression analysis showed that R.H. accounted for 4%, ambient temperature for 11%, and water temperature for 76% of the total sum of squares. Temperature of the evaporating surface is concluded, therefore, to be the variable of major importance in determining the evaporation rate when water is available for evaporation.

- (4335) THE HYDRAULICS OF STRUCTURES USED IN SOIL AND WATER CONSERVATION WORKS.
- See U. S. Department of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Division; Corn Belt Branch, Project 1723, and Illinois State Water Survey Division Project No. 1865.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
 - (c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma.
 - (d) Experimental and field investigation, applied research for design.
 - (e) Experiments employ small scale models as well as full size structures tested under simulated natural conditions to develop designs for structures needed for soil and water conservation. Closed conduit spillway entrances including drop inlets, hood inlets, and orifice plates are tested. Debris guards are tested using full size structures to provide verification of the small models.
 - (g) Three proposed standard trash rack designs have been tested with hay trash and with stick trash. Preliminary evaluation of the results indicates the need to have a rack of sufficient cross-section placed away from high velocity flow near the intake. A vertical panel (skirt) extending above and below intake crest elevation will keep out floating debris.
- (4336) DESIGN AND CALIBRATION OF DEVICES FOR THE MEASUREMENT OF RUNOFF.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
 - (c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma.
 - (d) Experimental, applied research.
 - (e) The measuring devices tested are used in the hydrology research program of the Agricultural Research Service. Sites for runoff measuring stations are surveyed and then modeled in the laboratory. Proposed structures are placed in the model and tested to develop a satisfactory design. The final design is calibrated by model tests. All current work is on specific sites and no general experiments are done.
 - (g) Model calibrations were completed during the past year for two supercritical flow flumes for measuring discharge rates up to 18,500 cubic feet per second. A V-notch and highway culvert combination runoff measuring station was rated by model tests.
 - (h) "Walnut Gulch Supercritical Measuring Flume," by W. R. Gwinn, Amer. Soc. Agric. Engin. Trans. 7(3): 197-199, 1964.
- (4337) HYDRAULICS OF FLOW IN VEGETATION LINED CHANNELS.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
 - (c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma.
 - (d) Experimental, applied research.
 - (e) Channels or portions of channels are built full size on the outdoor hydraulic laboratory grounds. These are planted to the vegetation being investigated and then tested by flowing water at selected times. Friction factors and permissible velocities (or tractive force values) are determined. In recent years the establishment phase of vegetal channels has received the greater emphasis. This has included the evaluation of temporary, fabricated liners of jute, glass fiber, and asphalt.
 - (g) Analysis only past year.
- (4338) HYDRAULICS OF UNSTEADY FLOW IN OPEN CHANNELS.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
 - (c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma.
 - (d) Experimental, applied research.
 - (e) Studies are made of unsteady flow phenomena occurring in the runoff process. Included are investigations of overland flow, spatially varied unsteady flow in channels, and flood wave movement in channels. The initial phase of the study is an analytical one utilizing existing knowledge and theory. This phase will be followed by a large scale outdoor laboratory study to test hypotheses and evaluate coefficients.
 - (g) Velocity distribution measurements have been made in a 400-foot long by 30-foot wide, V-shaped, grass-lined channel conveying a spatially varied flow. Momentum and velocity head coefficients have been determined. Some exploratory unsteady state, spatially varied flow tests have been performed on the same channel.
- (4339) RUNOFF CHARACTERISTICS OF AGRICULTURAL AREAS IN THE RED PRAIRIE OF OKLAHOMA.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
 - (c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma.
 - (d) Field investigation, applied research for design.
 - (e) Three watersheds, 17 acres, 92 acres, and 206 acres in size and covered with native grass, are instrumented to measure rainfall and runoff. Annual water yield as well as peak flood flows are determined. Selected runoff events provide data for distribution graphs or unit hydrograph development. Data are on hand from continuous measurements since 1951.
 - (g) Data are on hand from continuous measurements since 1951.
- (4340) SEDIMENT PRODUCTION, MOVEMENT AND DEPOSITION IN THE WASHITA RIVER BASIN, OKLAHOMA.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
 - (c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma.
 - (d) Field investigation, applied research.
 - (e) Suspended sediment sampling and total sediment transport determinations are made at selected tributary and main stream locations in the Washita River Basin. These samples are analyzed for size distribution.
 - (g) Analyzing available data.
- (4341) STREAM CHANNEL STABILIZATION AND SEDIMENT CONTROL WORKS IN CHANNELS OF THE WASHITA RIVER BASIN.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
 - (c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma.
 - (d) Field investigation, applied research.
 - (e) Selected reaches of channels representing different geologies, soils, and flow regimes are being established for detailed studies of stream channel morphology. Information is being obtained on cross-sections, slopes, thalweg lengths, alignments, vegetation, and bed and bank materials. Any control works are completely identified as to location, orientation, shape, size, and materials. Flow history will be recorded, including both water and sediment. Changes in channel conditions, or lack of change, will be related to flow history and other controlling factors for the development of criteria for stable channel design.
 - (g) Analyzing available data.
- (4342) PRECIPITATION CHARACTERISTICS INFLUENCING RUNOFF FROM AGRICULTURAL WATERSHEDS IN THE WASHITA RIVER BASIN, OKLAHOMA.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
 - (c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma.
 - (d) Field investigation, applied research.

- (e) A network of 170 recording precipitation gages has been established on a 3-mile grid in an 1100-square mile area in the central portion of the Washita River Basin. The precipitation characteristics will be analyzed to determine and evaluate precipitation parameters useful in estimating runoff.
- (g) Analyzing available data.
- (4343) RUNOFF PRODUCTION BY UNIT SOURCE AREAS IN THE WASHITA RIVER BASIN, OKLAHOMA.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
- (c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma.
- (d) Field investigation, applied research.
- (e) Small watersheds generally not exceeding 100 acres in size, each representing a single soil-cover combination are being instrumented to measure rainfall, runoff, and soil moisture. Information on the runoff producing characteristics of the unit source areas will be useful in the development of equations for predicting runoff from ungaged complex watersheds.
- (g) Analyzing available data.
- (4344) RELATION OF INTEGRATED CLIMATIC AND WATERSHED FACTORS TO STORM RUNOFF AND WATER YIELD OF THE WASHITA RIVER AND TRIBUTARIES, OKLA.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
- (c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma.
- (d) Field investigation, applied research.
- (e) A reach of the Washita River extending from Anadarko, Oklahoma, to Alex, Oklahoma, has been selected for study. This reach has a length of 78 river miles and a drainage area along this length of 1128 square miles. Gaging stations are being established near the mouth of 10 tributaries and at 6 sites along the main stem of the Washita River in this reach. Watershed characteristics are being measured and defined. The watershed land use and structures development will be inventoried periodically. Flood peaks, total flow and its rate-time distribution will be determined and related to climatic and land factors.
- (g) Analyzing available data.
- (4345) EXPLORATORY STUDY OF THE REGIMES OF WASHITA RIVER MAIN STEM FLOWS.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
- (c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma.
- (d) Analysis of record, applied research.
- (e) The flow history of the Washita River, Oklahoma, for the 10-year period 1941 to 1950 is being analyzed to: (1) Determine parameters characterizing the regime flows prior to development of upstream flood abatement measures; and (2) establish a base for reference in defining any future changes in flow regimes associated with conservation and treatment programs in tributary watersheds.
- (g) Analyzing available data.
- (4346) AQUIFER-STREAMFLOW RELATIONS, GROUND WATER BUDGET, WASHITA RIVER BASIN, OKLAHOMA.
- (b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
- (c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma.
- (d) Field investigation, applied research.
- (e) The alluvia and underground flow system of the Washita River Basin are being defined by use of drilling equipment and existing well logs. Permeability coefficients will be determined and ground water observation wells established. This is one part of a comprehensive research study of the total water budget in a portion of the Washita River Basin.
- (g) Analyzing available data.
- (4348) PRECIPITATION CHARACTERISTICS INFLUENCING RUNOFF FROM SELECTED AREAS IN TEXAS.
- (b) Laboratory project.
- (c) Mr. Walter G. Knisel, Hydraulic Engineer, P. O. Box 1147, Riesel, Texas.
- (d) Field investigation, applied research.
- (e) Rain gage networks are established on the Blacklands Experimental Watershed near Riesel, Texas, and on the Edwards Plateau near Sonora, Texas. Information is being obtained on amounts, duration, seasonal distribution, and other characteristics of rainfall to the extent that the characteristics influence runoff from agricultural watersheds. Data from 25 recording rain gages on 4,683-acre experimental area near Riesel, Texas, and 14 recording rain gages on 48-square-mile area near Sonora, Texas. A study of depth frequency for periods from 1 to 15 days has been completed and a report prepared.
- (g) Reported in USDA MISC. PUB. 945.
- (h) Reported in USDA MISC. PUB. 945.
- (4349) RELATION OF CLIMATIC AND WATERSHED FACTORS TO STORM RUNOFF AND TO WATER YIELD FROM AGRICULTURAL WATERSHEDS IN THE BLACKLANDS OF TEXAS.
- (b) Laboratory project.
- (c) Mr. Ralph W. Baird, Hydraulic Engineer, P. O. Box 1147, Riesel, Texas.
- (d) Field investigation, applied research.
- (e) Twenty watersheds at the Blacklands Experimental Watershed near Riesel, Texas, varying in size from approximately 3 acres to 5860 acres, have been equipped with precalibrated flumes or with current meter rated weirs to measure runoff rates. Precipitation is measured by recording rain gages. The land factors are determined by periodic inventory of crops, covers, and crop systems on the land. Relationships between climatic and land factors and the runoff produced are analyzed to develop prediction methods for estimating storm peaks and water yields.
- (g) The effects of conservation practices on storm runoff from major storms of infrequent occurrence is not great but is appreciable for many of the smaller storms.
- (h) Reported in USDA MISC. PUB. 945.
- (4350) RUNOFF PRODUCTION BY UNIT SOURCE AREAS IN THE BLACKLANDS OF TEXAS.
- (b) Laboratory project.
- (c) Mr. Ralph W. Baird, Hydraulic Engineer, P. O. Box 1147, Riesel, Texas.
- (d) Field investigation, applied research.
- (e) Ten watersheds of from one-fourth to twenty acres in size and with single land use on each are instrumented with precalibrated flumes to measure runoff. Soil moisture, tillage operations, and crop yields are also obtained. The relationships between the runoff and the associated precipitation as influenced by the land characteristics are investigated. These relationships will facilitate the prediction of runoff from ungaged watersheds composed of combination of these single soil-cover, sub-watersheds or unit source areas.
- (h) Reported in TAES Misc. Pub. 404, and USDA Misc. Pub. 945.
- (4351) SEDIMENT YIELD IN RELATION TO CLIMATIC AND WATERSHED CHARACTERISTICS OF AGRICULTURAL AREAS IN THE TEXAS BLACKLANDS AND THE EDWARDS PLATEAU.
- (b) Laboratory project.
- (c) Mr. Ralph W. Baird, Hydraulic Engineer, P. O. Box 1147, Riesel, Texas.
- (d) Field investigation, applied research.

- (e) At the Blacklands Experimental Watershed near Riesel, Texas, sediment yield measurements have been or are being made on twenty-four plots or watersheds varying in size from one-quarter to 5860 acres. These sediment yields are correlated with precipitation, runoff, topography, soils, land use, and conservation practices. The data are analyzed to develop techniques and procedures for estimating sediment yield and sources from ungaged watersheds. On Lowrey Draw in the Edwards Plateau area near Sonora, Texas, sediment range lines have been established, in cooperation with Soil Conservation Service, at two detention reservoir sites with drainage areas of 4.38 and 16.85 square miles. In addition, arrangements have been made for sampling the flow from the reservoir spillways.
- (g) In the Texas Blacklands sediment yields from watersheds of 100 to 200 acres having a large percent of cultivated crops have been reduced about 85 percent by changing to a complete conservation program.
- (4352) RELATION OF CLIMATIC AND WATERSHED CHARACTERISTICS TO STORM RUNOFF AND WATER YIELD IN THE EDWARDS PLATEAU AREA OF WEST CENTRAL TEXAS.
- (b) Laboratory project.
(c) Mr. Walter G. Knisel, Hydraulic Engineer, P. O. Box 1147, Riesel, Texas.
(d) Field investigation, applied research.
(e) Five detention reservoirs in Lowrey Draw are equipped with water level recorders. Runoff rates and volumes are measured by volume changes in the reservoirs. The watersheds above the reservoirs range in size from 686 to 10,787 acres. A current meter rated gaging station is at the outlet of the Lowrey Draw watershed which has a drainage area of 48 square miles. A rain gage network is used to determine the precipitation over the area. In addition to the development of the rainfall-runoff relationship for this area, a study will be made of the disposition of the water temporarily stored in the reservoirs.
- (g) A major storm of 7 to 12 inches occurred on the 48-square-mile watershed Sept. 19-24. A special storm report is being prepared.
- (4353) EVALUATION OF OPERATION AND DESIGN CRITERIA OF OLD TILE DRAIN SYSTEMS.
- (b) Laboratory project.
(c) Mr. Victor I. Myers, Research Agricultural Engineer, P. O. Box 267, Weslaco, Texas.
(d) Field investigation - applied research.
(e) A study to evaluate the effectiveness of some old existing tile systems in draining and leaching soils; to evaluate the functioning of tile drains with and without filter materials; and, to evaluate the adequacy of tile drain design criteria.
(g) Tile lines laid in certain soils, without filter or envelope materials provided, accumulate soil over a long period of time until they become plugged or only partially effective. Studies are shedding light on the occurrence of the salinity - clay mineral complex and interactions that influence movement of soil particles into drain lines.
- (4354) INFILTRATION RATES AND PROFILE CHARACTERISTICS IN RELATION TO THE OCCURRENCE OF SALINITY.
- (b) Laboratory project.
(c) Dr. Craig Wiegand, Research Soil Scientist, P. O. Box 267, Weslaco, Texas.
(d) Field investigation; applied research.
(e) The purpose of the work is to relate infiltration rates to the occurrence of salt-affected profiles. Infiltration rates are to be determined on about a dozen salt affected and adjacent non-affected profile pairs which have been chemically and physically characterized. The infiltration rates will be related statistically to the severity of salinization and to the chemical and physical properties of the profiles.
- (f) Completed.
(g) The final intake rate (5 hours) in the non-saline sites averaged about 3 times those of the adjacent saline sites. Analysis of variance revealed that saline profiles were higher in percent clay, are slightly elevated relative to the nonsaline sites and have greater surface slope than do the nonsaline sites. Multiple regression analyses predicted 95% of the variation in final intake rate. Differences in clay content surface elevation and soil slope are concluded to result in differences in leaching effectiveness of rainfall due to their influences on infiltration and runoff.
- (4355) EFFECTS OF BENCHING AND TERRACING ON MOISTURE CONSERVATION ON SLOPING HARDLANDS OF THE SOUTHERN GREAT PLAINS.
- (b) Laboratory project.
(c) Mr. Victor L. Hauser, Agricultural Engineer, Southwestern Great Plains Field Station, Bushland, Texas.
(d) Field investigation, applied and design research.
(e) 1. To test the feasibility of altering the configuration of the land to intercept, spread, and infiltrate surface runoff in contour basins. 2. To determine the extent to which such intercepted runoff will add to available soil moisture supplies and how such additional soil moisture may best be utilized for crop production. 3. To determine the relative value of the three types of terrace systems, conservation benching, graded, and level closed end for moisture conservation and crop production. 4. To measure runoff from well managed contour farmed hardland soils.
- (g) It has been found that graded and level terraces are equally effective in conserving runoff water under semi-arid conditions where 10 or 11 months of fallow preclude planting either wheat or grain sorghum. It has been found that the conservation bench terrace system is superior to either graded or level terraces in the conservation of runoff water.
- (4357) EFFECT OF CROPPING SYSTEMS AND CLIMATE ON RUNOFF, EROSION, AND CROP YIELDS UNDER BLACKLAND CONDITIONS.
- (b) Laboratory project.
(c) Mr. D. W. Fryrear, Agricultural Engineer, P. O. Box 748, Temple, Texas.
(d) Experimental - applied research.
(e) Runoff and soil loss are measured from 12 field scale (1 1/2 acre) plots representing a typical cultivated slope of Blackland Prairie soils. The plots are in three cropping systems with row cropping every year, in alternate years, and every third year. By taking soil moisture and crop residue measurements, in the future the interactions of varying climatic influences with crops and management are determined as a basis for determining runoff and erosion on farms and watersheds.
- (g) Statistical analysis of runoff results for 4-year period 1959-62 indicated no significant difference between plot replications or cropping systems but a significant difference in runoff for different years. Similar analysis of soil loss data for this period showed no significant difference between cropping systems, and a significant difference between plot replications and years. Complete statistical analysis of runoff, soil loss, and yield data will be made after the 1964 harvest.
- (4844) TESTING OF MATERIALS FOR IMPROVED SUBSURFACE DRAINAGE.

- (b) Laboratory project.
 - (c) Mr. Victor I. Myers, Research Agricultural Engineer, P. O. Box 267, Weslaco, Texas.
 - (d) Experimental; applied research.
 - (e) Laboratory tank studies will be made to evaluate drainage materials with particular emphasis on filters and new drain tube materials. One or more field installations will be made in which drainage materials will be compared and evaluated. Electric analogue studies will be made for predicting flow rates into tile lines.
 - (g) Laboratory studies with semi-rigid plastic lines have shown that the material can withstand loadings imposed by deep installation, to 9 feet, if installed in a narrow 10-inch width trench and if installed in an excavated cradle to provide some lateral strength.
- (4845) SOIL-WATER-PLANT RELATIONS OF IRRIGATED COTTON AS INFLUENCED BY DEPTH TO WATER TABLE.
- (b) Laboratory project.
 - (c) Mr. L. N. Namken, Research Soil Scientist, P. O. Box 267, Weslaco, Texas.
 - (d) Field investigation; applied research.
 - (e) A set of thirty-six lysimeters, one meter square and ten feet deep, are being utilized to study the influence of soil moisture level, water table depth and water table salt level treatments on evapotranspiration, vegetative growth and yield of cotton. The objectives of the project are: (1) To determine the contribution of a water table to the water requirement of cotton; (2) to study soil moisture use and extraction by cotton as influenced by various water table depths; and (3) to study the effect of water table salt concentration on salt movement and moisture uptake by the cotton plant.
 - (g) Total moisture use, lint yield, and plant dry weight of cotton grown with the water table at 3 feet were significantly less than from cotton grown with 6 and 9 feet deep water tables. The highly saline condition of the entire soil mass above the 3-foot water table apparently caused these differences. There was a significant interaction between moisture level and water table depth treatments on total moisture use, lint yields and dry weight production by cotton. Under high moisture conditions, cotton grown over a 9 foot deep water table had significantly greater total moisture use, lint yields and dry weight production than cotton grown with a water table of 6 feet. There was a complete reversal under the lower moisture treatment where cotton with the 6 foot deep water table had greater total moisture use, lint yields, and dry weight production than cotton with the 9 foot deep water table. Cotton under low soil moisture conditions (M-2) combined with a 9-foot water table depth had a 440 pound/acre reduction in lint cotton yields, a 33% reduction in dry weight production, and a 7.3 inch reduction in total moisture use compared with cotton under high soil moisture conditions (M-1) and a 9-foot water table depth. Evapotranspiration rates of cotton were influenced by the amount of moisture in the profile, stage of plant growth and water table depth. Maximum rates generally occurred under high soil moisture conditions after irrigations or rains during the bloom stage of plant growth. Maximum evapotranspiration rates by cotton under moisture level I were .22, .40, and .45 inch/day for the 3-, 6-, and 9-foot water table depths, respectively. Maximum rates under moisture level II were .20, .35, and .38 inch/day for the 3-, 6-, and 9-foot water table depths, respectively.
- (4846) EFFECT OF VARIOUS METHODS OF STUBBLE MULCH TILLAGE ON RUNOFF FROM UNIT SOURCE WATERSHEDS.
- (b) Laboratory project.
- (c) Mr. M. B. Cox, Agricultural Engineer, P. O. Box 128, Cherokee, Oklahoma.
 - (d) Field investigation; applied research.
 - (e) Comparison of three types of tillage tools for residue management on runoff from unit source watersheds ranging in size from 1.7 to 2.2 acres on land slopes from 2.2 to 3.5 percent, cropped annually to wheat. Six watersheds with three treatments and two replications.
 - (g) Treatment 1, large sweeps (8 ft.) conserved the most residue and produced the least amount of runoff; Treatment 3, chisel tool, was the next treatment for conserving residue, but more runoff resulted; Treatment 2, light disking and chisel tool, conserved the least residue and produced the most runoff.
- (4848) GRADED FURROWS FOR RUNOFF AND EROSION CONTROL.
- (b) Laboratory project.
 - (c) Mr. D. W. Fryrear, Agricultural Engineer, P. O. Box 748, Temple, Texas.
 - (d) Field investigation; applied research.
 - (e) Purpose of work is to determine relationships between furrow length and slope, runoff and soil loss, and to see if graded furrows will permit increased terrace spacing. Terrace spacing is doubled and a channel rather than a conventional ridged terrace is used to convey runoff water. Increased terrace spacing is accomplished by planting on 40-inch lister furrows on a 1 percent grade. The amount of runoff and soil loss from the furrows is measured along with rainfall intensities, soil moisture, and surface residues.
 - (g) Physical system was established in summer of 1963. Special techniques and methods of measuring runoff and soil loss have been designed and developed including sampling apparatus for separating runoff increments into various amounts to permit determination of timing of major portion of erosion. Limited runoff data collected in 1964 indicates slightly more runoff from furrows on a 1 percent grade than from furrows on the contour. Runoff data also show that furrows 300, 600, and 900 feet long on a 1 percent grade will convey at least 4.44, 2.85, and 2.06 inches per hour, respectively.
- (4849) EVALUATION OF DRAINAGE METHODS FOR THE NONIRRIGATED AREA OF THE LOWER RIO GRANDE VALLEY OF TEXAS.
- (b) Laboratory project.
 - (c) Mr. Ronald R. Allen, Agricultural Engineer, or Mr. Victor I. Myers, Research Agricultural Engineer, P. O. Box 267, Weslaco, Texas.
 - (d) Experimental and field investigation; applied research.
 - (e) The purpose of the study is to compare the effectiveness and cost of installation operation and maintenance of three drainage methods; open drain ditches, subsurface drain tile, and drainage wells in reduction of soil salinity and control of a ground water table.
 - (g) An underlying permeable sand aquifer limits installation depth and effectiveness of open drain ditches and subsurface drain tile. Pump drainage by wells has incurred considerable expense for the small area affected.
- (5211) LIMITED IRRIGATION OF GRAIN SORGHUM IN THE SOUTHERN PLAINS.
- (b) Laboratory project.
 - (c) Mr. J. T. Musick, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas.
 - (d) Field investigation; applied research.
 - (e) To determine number and timing of irrigations for most efficient use of limited irrigation and expected precipitation; plant spacing for

- most efficient use of limited water; and some soil moisture-plant growth-yield relationships under limited soil moisture conditions.
- (g) One or two well-timed seasonal irrigations resulted in good yields and efficient use of limited irrigation water which permitted a reduction in irrigation water requirements. In addition to considering soil moisture, proper timing of limited irrigation should consider expected seasonal rainfall and stage of plant development. Narrow row and plant spacings are necessary for most efficient use of water at higher yield levels.
- (5212) SOIL LOSS FROM THE ENDS OF LEVEL TERRACES AND THE EROSION OCCURRING BETWEEN TERRACES.
- (b) Laboratory project.
(c) Mr. M. B. Cox, Agricultural Engineer, P. O. Box 128, Cherokee, Oklahoma.
(d) Field investigation; applied research.
(e) Purpose of work is to determine soil losses from terraces and from different sections down-slope within terrace intervals. Runoff and soil loss are measured from a system consisting of 8 terraces and 20 small plots. Half of the area is clean tilled and half stubble mulched. Terraces are arranged in pairs, one concrete and one soil channel. Concrete lined channels are used to provide a permanent base for measuring soil movement into terrace channels. Plots, located at the ends of the pairs of terraces, permit determination of silt contribution from three sections of normal terrace intervals.
(g) Terrace installations are completed and 1963-64 runoff and soil loss data have been obtained. Data showed some variation between different pairs of terraces but marked similarity of both runoff and soil loss was obtained within pairs, i.e., between concrete and regular soil channel terraces. The small plot portion of the study is installed but no data have been obtained.
- (5213) WATER INTAKE AND DISTRIBUTION OF SOIL MOISTURE UNDER GRADED FURROWS ON PULLMAN SILTY CLAY LOAM.
- (b) Laboratory project.
(c) Mr. W. H. Sletten, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas.
(d) Field investigation; applied research.
(e) Determine water intake characteristics, storage, distribution, and irrigation efficiency of long furrows on Pullman silty clay loam soil.
(g) This soil has a high initial intake rate which rapidly drops to a very low basic rate. One to two inches of initial intake occurs during and soon after water passes a point in the furrow. The intake rate then declines rapidly to about 0.6 inch per hour for the first hour after runoff begins from a short furrow segment to a basic rate of 0.1 inch per hour or less about 4 hours later. Cutting off the water soon after it reaches the end of long furrows results in high application efficiencies, relatively good distribution and decreases tailwater runoff losses.
- (5214) DEVELOPMENT AND TEST OF A SIMPLE SYSTEM TO CLARIFY PLAYA WATER WITH FLOCCULENTS AND THE USE OF AN IRRIGATION DITCH AS A SETTLING BASIN.
- (b) Laboratory project.
(c) Mr. Victor L. Hauser, Agricultural Engineer, Southwestern Great Plains Field Station, Bushland, Texas.
(d) Field investigation; applied and design research.
(e) To develop a simple system for removing sediments from muddy playa lake water. This research project will be an effort to assemble relatively simple equipment to clarify muddy lake water prior to injection into a shaft as a means of storing runoff water and thus prevent its loss to the atmosphere by evaporation.
- (f) This experiment was terminated early in 1963.
(g) The system design specified in the research outline is not capable of removing enough sediment to be used in widespread recharge projects. The modified system including a sand filter did remove enough sediment to be used in recharge work but the capacity of the system is low.
- (5216) GEOPHYSICAL EXPLORATION OF A PLAYA AND ITS WATERSHED.
- (b) Laboratory project.
(c) Mr. Wayne Clyma, Agricultural Engineer, Southwestern Great Plains Field Station, Bushland, Texas.
(d) Determine the stratigraphy of a playa and its watershed using surface electrical resistivity and electric and gamma-ray well logging equipment.
(e) The playa will be surveyed with the electrical resistivity equipment on a 500 foot grid. Data will be collected and analyzed according to standard practice. Each bore hole drilled on the playa watershed will be logged electrically and these data correlated with the drillers log and the stratigraphy and properties of each lithologic member.
(f) Initiated in 1963, field and laboratory work is continuing.
- (5217) RUNOFF PRODUCTION BY UNIT SOURCE AREAS IN THE EDWARDS PLATEAU OF TEXAS.
- (b) Laboratory project.
(c) Mr. Walter G. Knisel, Jr., Research Hydraulic Engineer, P. O. Box 1147, Riesel, Texas.
(d) Field investigation; applied research.
(e) Six watersheds, five selected, one installation completed in 1963 and three under construction in 1964. These watersheds are all in range areas of different soil and geologic formations, and runoff will be measured by precalibrated flumes. The relationship between the runoff and the associated precipitation as influenced by range use, geology, and soils are investigated.
- (5218) THE DURABILITY AND EFFECTIVENESS OF DRAINAGE MATERIALS UNDER FIELD CONDITIONS.
- (b) Laboratory project.
(c) Mr. Victor I. Myers, Research Agricultural Engineer, P. O. Box 267, Weslaco, Texas.
(d) Field investigation; applied research.
(e) A field installation of old and new drainage tile, pipe and tubing is being made to evaluate the durability, and effectiveness of the materials. In addition, the investigation includes a study of the effectiveness of providing envelope material to increase the flow of water and decrease movement of sediment into drain lines under stratified soil conditions.
(f) Initiated in 1963 as a field study.
(g) A field installation of 1/8 mile lines has been completed consisting of concrete with and without fiberglass envelope material, and asphalt fiber pipe with a fiberglass envelope. This will be a test of the durability and effectiveness of drainage materials.
- (5577) PHOTOGRAMMETRY AND REMOTE SENSING TO DETERMINE THE MOISTURE STATUS OF PLANTS AND SALINITY IN SOILS.
- (b) Laboratory project.
(c) Mr. Victor I. Myers, Research Agricultural Engineer, P. O. Box 267, Weslaco, Texas.
(d) Part of the project is theoretical basic research and the remainder is applied research.
(e) The purpose of the project is to (1) test and adapt radiation measuring instrumentation for aerial measurement of plant temperatures and soil moisture stresses, and

- (2) improve procedures for rapid prediction of plant moisture stress and soil salinity conditions from the air, using remote sensing instrumentation and aerial photography.
- (g) Ektachrome infrared aerial photographs were used for estimating salinity in the 0-5 foot profile using nonirrigated cotton as an indicator plant. On the basis of color tones it was possible to distinguish six levels of salinity. Infrared radiometer measurements of cotton leaf temperatures were made on the ground and from an airplane. The limited aerial measurements made compared favorably with ground measurements. Statistical studies of the temperature data taken on the ground indicate that soil salinity can be predicted from cotton leaf temperatures with reasonable accuracy.
- (5578) AERATION MEASUREMENTS FOR DETERMINING DRAINAGE NEEDS.
- (b) Laboratory project.
- (c) Dr. Ross W. Leamer, Research Soil Scientist, P. O. Box 267, Weslaco, Texas.
- (d) Determine the suitability of (1) bare platinum electrodes, (2) membrane covered gold electrodes, and (3) gas chromatograph for indicating soil drainage conditions.
- (e) Aeration measuring devices are installed in a soil column in which water table level can be varied. The response of aeration measurements resulting from changes in water table level determine sensitivity to drainage conditions.
- (f) Initiated in 1964. Continuing.
- (5579) EFFECT OF WIND ON A FALLING WATERDROP.
- (b) Laboratory project.
- (c) Dr. E. L. Skidmore, Agronomy Dept., Waters Hall, Kansas State University, Manhattan, Kansas.
- (d) Laboratory investigation; basic research.
- (e) Purpose of research is to determine influence of wind on the velocity of a falling raindrop; to determine effect of wind on path of drop; to determine effect on horizontal acceleration of drop; and to determine effect of wind on kinetic energy and momentum of raindrops. The experiment is being conducted in a wind tunnel-rain tower facility where conditions of wind and other variables can be rather precisely controlled.
- (g) Problems associated with drop formation and lighting required for photographic techniques are presently being worked on and resolved. Experimental data will be taken during 1965.
- (5580) LIMITED IRRIGATION OF WHEAT AND SORGHUM IN A FALLOW-WHEAT-SORGHUM SEQUENCE.
- (b) Laboratory project.
- (c) Mr. J. T. Musick, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas.
- (d) Field investigation; applied research.
- (e) Determine response to limited irrigation of winter wheat and grain sorghum at two critical stages of plant growth on yields, water use efficiencies, and plant characteristics; and to evaluate the ability of an extended pre-seasonal crop period (11 to 12 months preceding both sorghum and wheat) to supply soil moisture storage at planting and thus decrease irrigation water requirements.
- (5581) TIMING OF PRESEASONAL IRRIGATION IN RELATION TO EFFICIENCY OF SOIL MOISTURE STORAGE.
- (b) Laboratory project.
- (c) Mr. W. H. Sletten, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas.
- (d) Field investigation; applied research.
- (e) Determine relationship between the storage efficiency of preseasonal irrigation water and timing of irrigation and the effect of antecedent soil moisture on storage efficiency of preseasonal precipitation and/or irrigation.
- (5582) WATER REQUIREMENTS OF MARRS ORANGES, RED BLUSH GRAPEFRUIT, AND VALENCIA ORANGES IN THE RIO GRANDE VALLEY.
- (b) Laboratory project.
- (c) Mr. Marvin D. Heilman, Research Soil Scientist, P. O. Box 267, Weslaco, Texas.
- (d) Field investigation - applied research.
- (e) This field investigation is designed to provide quantitative information on moisture use of Marrs and Valencia oranges and red blush grapefruit in the Rio Grande Valley. From this data water management recommendations will be made for citrus production grown under conditions of a limited water supply. In addition, the investigations will determine the effects of the various citrus varieties.
- (5583) VARIATION OF SATURATED HYDRAULIC CONDUCTIVITY OF HOUSTON BLACK CLAY WITH SOIL DEPTH AND WITH DIAMETER OF SOIL CORES.
- (b) ARS-SWC, Blackland Conservation Experiment Station, Temple, Texas. Laboratory project.
- (c) Mr. J. L. Tackett, Research Soil Scientist, P. O. Box 748, Temple, Texas 76502.
- (d) Experimental and basic research.
- (e) Saturated hydraulic conductivity will be determined for each 6-inch interval of undisturbed 9-foot soil column of 16- and 29-inch diameter and for 3-inch long soil cores of 3- to 3 7/8-inch diameter. The purposes will be (1) to determine the saturated flow rate of water through undisturbed cores of Houston Black clay profiles and through various layers of the profile, (2) to develop methods and procedures for utilizing large diameter cores for measuring the hydraulic conductivity of soils, (3) to study the relation between core size and saturated hydraulic conductivity, and (4) to determine the relation between direction of water flow and hydraulic conductivity.
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- U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.
- SOUTHWEST BRANCH, P. O. Box 2326, Riverside, Calif., Mr. W. W. Donnan, Branch Chief.
- (151) LINING OF IRRIGATION CANALS AND RESERVOIRS.
- (b) Laboratory project, in cooperation with the Utah State University and Bureau of Reclamation.
- (c) Dr. C. W. Lauritzen, Soil Scientist, Utah State University, Mechanic Arts, 130, Logan Utah.
- (d) Experimental; basic and applied research.
- (e) Linings for irrigation canals and reservoirs are being tested to develop more effective and lower cost methods of reducing seepage losses in irrigation systems. The investigation included: (1) Evaluation of physical properties of lining materials; (2) model testing of linings in an outdoor laboratory; and (3) field testing at selected sites to determine relative durability under varying subgrade and climatic conditions.
- (g) After nearly 10 years both vinyl and polyethylene film employed as buried linings continue to provide effective seepage control. A built-up asphalt coated jute lining is highly effective after 7 years. After 9 years as an exposed canal lining the tensile and elongation of butyl sheeting remained unchanged. After 17 years of exposure on a walking deck butyl sheeting retained 80 percent of the original tensile and elongation.
- (2117) WATER REQUIREMENTS IN IRRIGATED AREAS OF SOUTHWEST.

- (b) Laboratory project in cooperation with State and Federal agencies.
- (c) Mr. Dean C. Muckel, Agricultural Engineer, P. O. Box 8014, University Station, Reno, Nevada.
- (d) Field experiments and office analysis. Applied research.
- (e) To determine the consumptive use of water by crops, phreatophytes, and other vegetation, and net irrigation supply requirements. To develop empirical formula from climatological and other data for determining rates of consumptive use.
- (2180) EVAPORATION LOSSES FROM RESERVOIRS AND LAKES.
- (b) Laboratory project in cooperation with State of California, counties and other agencies.
- (c) Mr. Dean C. Muckel, Agricultural Engineer, P. O. Box 8014, University Station, Reno, Nevada.
- (d) Experimental; compilation and analysis of data. Applied research.
- (e) To determine evaporation losses from reservoirs and lakes and develop empirical formulas from climatological data for computing monthly evaporation. Cooperative field measurements are being made of pan evaporation at stations in California ranging from near sea level in Santa Barbara County to 9,194 feet elevation at Kaiser Pass in the Sierra-Nevada Mountains.
- (2181) ARTIFICIAL RECHARGE OF GROUND WATER FOR IRRIGATION IN CALIFORNIA.
- (b) Laboratory project in cooperation with the California Department of Water Resources.
- (c) Mr. Leonard Schiff, Hydraulic Engineer, 4816 East Shields Avenue, Fresno 3, Calif.
- (d) Experimental; laboratory and field investigations, applied research.
- (e) To efficiently store imported water underground in quantity and of a quality needed in various locations. The objectives are: (1) To determine the physical and chemical characteristics of surface soil and substrata on selected recharge sites and to relate these characteristics to infiltration and percolation rates, and to lateral aquifer flow; (2) to determine the feasibility of recharge irrigation (deep percolation by heavy irrigation of crops) as a means of storing water underground; (3) to determine the effect on recharge of the quality of water reaching the groundwater table under selected site conditions, and on the quality of the groundwater; and (4) to prepare a recharge guide which permits the evaluation of a site for recharge, suggests methods and systems of recharge to be used and indicates the quality of groundwater that may be expected as a result of recharge.
- (h) "Hydraulic Conductivity of Uniform, Stratified, and Mixed Sands," by J. J. Behnke and Leonard Schiff. Journ. Geophys. Res., 68-16, pp. 4769-4775, 1963.
 "A Strain Gage Pressure Cell for the Rapid Determination of Hydraulic Conductivity of Soil Cores," by W. C. Bianchi and E. E. Haskell, Jr. Proc. ASTM, Vol. 63, pp. 1227-1234, 1964.
 "Fixed-Position Device for Sampling Soil Solution in Depth," by E. E. Haskell, Jr. and W. C. Bianchi. Jour. Am. Water Works Assoc., Vol. 56(5):664-666, 1964.
 "Moisture Changes in Deep Soil Profiles Beneath Artificial Ground Water Recharge Sites," by E. E. Haskell, Jr. and W. C. Bianchi. ARS Res. Rept. 372, 1964.
 "Devices for Measuring Soil-Water Movements in Designing Recharge Facilities," by Leonard Schiff. Trans. ASAE, Vol. 7(1):67-69, 1964.
 "Some Physical and Chemical Considerations in Artificial Ground-Water Recharge," by Leonard Schiff and Kenneth L. Dyer. Pub. No. 64, Intl. Assoc. Sci. Hydrology, pp. 374-378, 1964.
 "Ground-Water Recharge Hydrology," by Leonard Schiff. Ground Water, Vol. 2(3), July 1964.
- (2650) EFFECT OF WATER TABLE DEPTH ON IRRIGATION REQUIREMENTS AND YIELD OF LAHONTAN ALFALFA.
- (b) Laboratory project, in cooperation with the Nevada Agricultural Experiment Station.
- (c) Mr. Rhys Tovey, Agricultural Engineer, ARS, Box 8014, University Station, Reno, Nevada.
- (d) Experimental; applied research.
- (e) To determine surface-irrigation requirements of Lahontan alfalfa grown on three soil textures with constant water tables at various depths, and on well-drained soil in the absence of a water table; to determine the effect of plant growth stage on the rate of water use by Lahontan alfalfa; to determine the relation between the use of water by alfalfa under various water table conditions, evaporation from porous atmometer bulbs, and evaporation from a Weather Bureau evaporation pan; and to evaluate the effects of a fluctuating water table on the yield and growth rate of alfalfa.
- (f) Completed.
- (g) The frequency and duration of water table fluctuations must be controlled to sustain alfalfa production. Significant results of the lysimeter study, for areas with growth and climatic conditions similar to those of the study area are as follows: (1) Excess water must be removed from the root zone of alfalfa plants adapted to 2-foot static water tables within three days to insure optimum crop production. (2) Alfalfa root system deterioration became progressively worse as the fluctuation or submergence intervals exceeded four days.
- (h) "Water Table Fluctuation Effect on Alfalfa Production," by Rhys Tovey. Univ. of Nev. Agr. Expt. Sta. Tech. Bul. No. 1 (1964).
- (3556) FARM CONVEYANCE AND WATER APPLICATIONS.
- (b) Laboratory project, in cooperation with the Utah State University.
- (c) Dr. C. W. Lauritzen, Soil Scientist, Utah State University, Mechanic Arts, 130, Logan Utah.
- (d) Experimental; basic and applied research.
- (e) New methods and equipment for conveying and applying irrigation water are being developed. The hydraulic properties of lay-flat tubing are being studied and new materials are being evaluated to determine their use in conveyance structures.
- (g) Two devices for regulating and measuring water deliveries from irrigation canals and ditches have been developed. These devices are essentially leakproof and simple to regulate.
- (h) "Hydraulic and Geometrical Relationships of Lay-Flat Tubing," by Allan S. Humphreys and C. W. Lauritzen. USDA Technical Bulletin No. 1309, October 1964.
- (3558) LABORATORY MODEL AND FIELD STUDIES OF REDUCING SEEPAGE IN SANDS WITH BENTONITE.
- (b) Laboratory and field project, in cooperation with the Nevada Agricultural Experiment Station.
- (c) Mr. Myron B. Rollins, Research Soil Scientist, Agricultural Research Service, P. O. Box 8014, University Station, Reno, Nevada.
- (d) Experimental; applied research.
- (e) To determine factors influencing blanket treatments and sediment penetration and retention involved with sealing irrigation canals or reservoirs with bentonite, and to develop procedures to obtain effective seals. Laboratory experimentation is being done with sands placed in lucite cylinders 3 inches in diameter and 2 feet long. Folds 20 x 40 feet are used in field tests. Bentonite is applied by blanket treatment and by dispersing it in the water. Numerous aspects concerning the chemical, physical, and mineralogical properties of the bentonites, waters, and sands will be evaluated.
- (g) Investigations, to date, suggest that effective seals can be obtained within certain unknown limitations for the dispersion or sediment treatment. Blanket treatments are very

- effective if kept moist.
- (h) "Field Experiments on Sealing Permeable Fine Sand With Bentonite," by M. B. Rollins, Soil Sci. Soc. Am. Proc. 28:268-271, March-April 1964.
- (3560) EVAPOTRANSPIRATION OF HUMBOLDT MEADOW VEGETATION AS MEASURED WITH LYSIMETERS.
- (b) Laboratory and field project, in cooperation with University of Nevada Agr. Expt. Sta. and Nevada State Department of Conservation and Natural Resources.
- (c) Mr. Anthony S. Dylla, Agricultural Engineer, P. O. Box 8014, University Station, Reno, Nevada.
- (e) To measure the evapo-transpiration of meadow vegetation in the Humboldt Basin area which subsists primarily under shallow water table conditions. The data will be used to determine areal use of ground waters by native vegetation and phreatophytes and to native vegetation and phreatophytes and to develop methods of more efficient utilization of those water supplies.
- (f) Progress report covering three years data underway.
- (g) Evapo-transpirational rates are being obtained by water use measurements of meadow grasses growing in plastic lysimeters. Vegetative growth, soil moisture, water table, and weather data are being collected to which evapo-transpiration rates from tanks can be related.
- (h) "Evapotranspiration Studies on Native Meadow Grasses, Humboldt Basin, Winnemucca, Nevada," by A. S. Dylla and Dean C. Muckel, Univ. of Nev. Agr. Expt. Sta. Rept. Series No. R-9, October 1964.
- (3872) DYNAMIC SIMILARITY IN PIPE ELBOW FLOW METERS.
- (b) Laboratory project.
- (c) Mr. Lloyd E. Myers, Director, Water Conservation Laboratory, Route 2, Box 816-A, Tempe, Arizona.
- (d) Experimental; applied research.
- (e) ASA, class 125, cast iron, 90-degree, flanged elbows of 3-, 6-, 10-, and 12-inch diameters from five manufacturing sources were calibrated to determine the expected accuracy of flow measurements made with uncalibrated elbow meters. Effects of various fittings and installations on the calibration were determined for 3-inch diameter elbows.
- (f) Reactivated.
- (g) Uncalibrated elbow meters can be expected to be accurate within 5 percent if properly installed.
- (3873) GROUND COVERS AND OTHER STRUCTURES FOR COLLECTING AND STORING PRECIPITATION.
- (b) Laboratory project, in cooperation with the Utah State University.
- (c) Dr. C. W. Lauritzen, Soil Scientist, Utah State University, Mechanics Art, 130, Logan, Utah.
- (d) Experimental and applied research.
- (e) There are areas in many regions where water for livestock and even culinary uses is scarce or nonexistent, yet considerable water in the form of precipitation falls each year. As an example, the precipitation on one acre of land in an 8-inch rainfall area amounts to 217,248 gallons. This is enough to supply water to more than 200 head of cattle for 100 days. This study includes the development and testing of materials for ground covers and storage facilities to be used for the collection and storage of water in low rainfall areas together with the design and operation of these facilities.
- (g) Ground covers and closed storage structures have been developed for intercepting and storing precipitation. To satisfy the need for a name this combination of structures has been termed a "Rain Trap." Butyl sheeting continues to be the most satisfactory material for both the interceptor and the storage reservoir. Other materials are being investigated, and there are indications that some of these will be less expensive and reasonably serviceable as ground covers. Modifications have been made in the design and fabrication of ground covers and storage bags made of butyl to improve their performance.
- (4358) FLOOD WAVE MOVEMENT AND ROUTING IN ALLUVIAL CHANNELS.
- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
- (c) Mr. R. V. Keppel, Agricultural Engineer, P. O. Box 3926, Tucson, Arizona.
- (d) Experimental, field investigation.
- (e) Water level recorders are located at 2,000-foot intervals in a 3-mile reach of natural channel. The reach has a gaging flume at the inlet and at the outlet, and major tributary inflow is gaged. Flood waves generated by cloudburst type thunderstorms are being studied.
- (g) Propagation of the peak of the flood wave for discharges between 1000 and 2000 cfs took place at velocities of 10-15 feet per second, as compared with velocities of 5-7 feet per second for the front of the wave moving on a dry channel bed.
- (4359) PRECIPITATION CHARACTERISTICS INFLUENCING RUNOFF FROM SEMIARID WATERSHEDS.
- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
- (c) Mr. H. B. Osborn, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona.
- (d) Experimental, field and laboratory; basic research.
- (e) Rainage networks with densities of one recording gage per square mile are being operated on the 58-square-mile Walnut Gulch watershed in southeastern Arizona and the 67-square-mile Alamogordo Creek watershed in northeastern New Mexico. The walnut Gulch study is augmented by horizontal-search 3-cm. radar. Objectives of the study are to determine precipitation parameters of importance in predicting runoff and sediment yield, and to give particular attention to the small area, highly intense, convective summer thunderstorms typical of the region.
- (g) Data from Walnut Gulch watershed for a 7-year period of record indicate that summer convective thunderstorms are elliptical in shape with the major axis approximately 1.5 times the minor axis. Within the boundary of the Walnut Gulch watershed, 80% of the storms cover less than 4 1/2 square miles in area, and 96% cover less than 10 square miles. Maximum runoff events are typically the result of multi-celled storms separated in space and time. On the Alamogordo Creek watershed, convective thunderstorms are of greater intensity and larger areal extent than at Walnut Gulch. The difference is due to the greater amount of precipitable water in the air mass in eastern New Mexico as compared with southeastern Arizona, and to the fact that frontal action is more common thus giving an added lift to convective storm cells.
- (h) "Effect of Storm Duration on Runoff from Rangeland Watersheds in the Semiarid Southwestern United States," by H. B. Osborn. Bul. of International Assoc. Scientific Hydrology. Dec. 1964.
- (4360) RUNOFF FROM COMPLEX WATERSHEDS AS INFLUENCED BY CLIMATIC AND WATERSHED CHARACTERISTICS.
- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation

- Service.
- (c) Mr. R. V. Keppel, Agricultural Engineer, P. O. Box 3926, Tucson, Arizona.
 - (d) Experimental; applied research.
 - (e) On semiarid rangeland watersheds up to 43,000 acres in size, runoff measurements are being maintained, and an attempt is being made to relate water yield to climatic and watershed characteristics, and to evaluate the effects of a range conservation program on rates and amounts of flood runoff and on net water yields. A new design of critical depth flume with capacities up to 22,500 cfs is being used to gage the flashy, sediment-laden flows.
 - (g) On 5 Walnut Gulch watersheds ranging from 560 to 36,900 acres, water yield decreases exponentially with the 0.3 power of the watershed size. All of the water yields to date have occurred from June to September as a result of intense convective thunderstorms. On the Alamogordo Creek Watershed (43,000 acres), flow events originating on the central portion of the valley floor cause a flat-top hydrograph with a sustained peak lasting 2 to 3 hours. It is believed that this is caused by unusually large valley storage located upstream from a channel discontinuity. On the other hand, runoff events originating on the highly incised southeast or southwest branch of the main stem are sharp-peaked.
- (4361) THE ROLE OF VALLEY AND CHANNEL MATERIALS AND VEGETATION IN THE HYDROLOGY OF SEMI-ARID WATERSHEDS.
- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
 - (c) Mr. K. G. Renard, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona.
 - (d) Experimental, field investigation.
 - (e) Measurements from tandem gaging stations are utilized to evaluate the losses that occur as runoff traverses ephemeral stream channels. Records from shallow wells show depletion patterns of the transmission loss water.
 - (g) Losses up to 25 acre-feet-per-mile of channel have been measured on one reach of channel in a single flash flood. Records from wells in both the local and regional water tables indicate that in one reach of the main channel, most of the water is dissipated by evaporation and transpiration, while in another reach there may be some movement from the channel alluvium down to the regional water table.
- (4362) THE HYDROLOGY OF SEMI-ARID WATERSHEDS AS INFLUENCED BY CHARACTERISTICS OF SOIL AND NATIVE VEGETATION.
- (b) Laboratory project; cooperative with Ariz. and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
 - (c) Dr. J. L. Gardner, Botanist, P. O. Box 3926, Tucson, Arizona.
 - (d) Experimental, field and laboratory. Basic research.
 - (e) Interrelations of soils and native vegetation as they influence water and sediment yield are being evaluated on rangeland watersheds of 100 to 43,000 acres in Arizona and New Mexico. Supplementary to studies on entire watersheds, infiltrometer studies on 6 x 12' plots are in progress. A primary objective of the infiltrometer studies is determination of parameters of rangeland vegetation most effective in evaluating its influences on runoff and sediment production on watersheds.
 - (g) On the infiltrometer plots, maximum runoff is reached in about half the time on areas supporting brush as compared to those supporting grass. On small watersheds above stock tanks, average annual sediment pro-
- duction -- but not runoff -- is logarithmically correlated with basal area of grass cover.
- (h) "Soil and Vegetation Parameters Affecting Infiltration Under Semiarid Conditions," by D. R. Kincaid, J. L. Gardner, and H. A. Schreiber. Bul. of International Assoc. Scientific Hydrology, No. 65, pp. 440-453, 1963.
- (4363) HYDROLOGIC DATA REDUCTION WITH ANALOG-TO-DIGITAL CONVERTER.
- (b) Laboratory projects, cooperative with the Arizona and New Mexico Agricultural Experiment Stations.
 - (c) Mr. H. B. Osborn, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona.
 - (d) Experimental; laboratory.
 - (e) Hydrologic records in analog form are being reduced to digital form by means of an automatic analog to digital converter. Information is transferred primarily from rainfall charts to punched cards for future computer programs.
- (4364) RUNOFF AND SEDIMENT MOVEMENT ON UNIT SOURCE WATERSHEDS AS INFLUENCED BY MICRO-CLIMATE, WATER BALANCE, SOIL AND VEGETATION.
- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
 - (c) Mr. H. B. Osborn, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona.
 - (d) Experimental, field and laboratory. Basic research.
 - (e) Runoff and sediment yields are being measured from several small, single soil-cover subwatersheds located within larger experimental watersheds having mixed soil-cover situations. Objectives are to evaluate the effects of various, soil-vegetation complexes, microclimate and water balance phases on local runoff and sediment production, and to identify and characterize unit source-areas controlling the net storm runoff and sediment yields of larger, more complex watersheds.
 - (g) Average annual sediment yield from small predominantly grass-covered watersheds is about 1%, by weight, of their water yield. Sediment yield measured from predominantly brush-covered watersheds ranges from around 2%, by weight, of water yield upward.
- (4365) SEDIMENT MOVEMENT ON COMPLEX WATERSHEDS AS INFLUENCED BY CLIMATE AND WATERSHED CHARACTERISTICS.
- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
 - (c) Mr. Kenneth G. Renard, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona.
 - (d) Experimental, field and laboratory.
 - (e) The objectives of this study are: (1) to determine the relationship of sediment production on unit source areas to sediment yields of complex watersheds, (2) to develop methods for sediment yield prediction, and (3) to develop methods for reducing sediment yields from semiarid rangeland watersheds in the Southwest. Integrated depth samples of suspended sediment are being collected, and single-stage samples by automatic samplers. Total load and particle sizes are being determined for correlation with storm and runoff measurements on several experimental watershed with varying soil, vegetation characteristics, and drainage features. Studies will be carried out over a number of years during which effects of changing range cover and corresponding changes in flow regimes of the watersheds may be evaluated.
 - (g) Sufficient samples have not as yet been collected or analyzed to develop sediment

rating curves nor to determine the suspended sediment load associated with the individual hydrographs. Suspended sediment samples collected in the mainstream of Walnut Gulch have been found to vary between 2 and 8 percent by weight. Unfortunately, these results have been confined so far to relatively small discharges. The following are indications from the samples analyzed to date: (1) The sediment peak precedes the hydrograph peak. (2) The sand load is relatively low in the samples collected before the hydrograph peak, and from the peak on is higher and seems to be more closely related to the actual discharge than are the small fractions. (3) Silt load is heavy at the sediment peak and drops off thereafter, i.e., clay to silt ratio rises after the sediment peak. (4) Correlation of consecutive depth-integrated samples is very good when the stage is not fluctuating rapidly. (5) The majority of the single stage samples on the main channel appear to agree well with the depth-integrated samples taken during the same period. (6) There is a considerable increase in the percentage of clay for samples taken in the mainstream as compared to samples taken upstream in the good grasslands. Greater gullying on other areas and bank erosion along the main channels are probably responsible for this increase.

(4368) DEVELOPMENT OF A PORTABLE IRRIGATION SPRINKLER EVALUATION DEVICE.

- (b) U. S. Dept. of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Division.
- (c) Mr. Rhys Tovey, Agricultural Engineer, ARS, Box 8014, University Station, Reno, Nevada.
- (d) Experimental; applied research.
- (e) (1) To develop a portable device that can be used in the design and evaluation of sprinkler irrigation systems and (2) to determine procedures for the use of the portable irrigation sprinkler evaluation device in measuring soil intake rates, sprinkler application rates and other factors pertinent to the efficient design of sprinkler irrigation systems.
- (g) A portable irrigation sprinkler evaluation device has been designed and constructed. Tests show that the device works satisfactorily. Procedures for measuring soil intake rates for sprinkler irrigation system design have been developed.

(4850) WATERSHED RELATIONS TO RECHARGE OF DIRECTLY ASSOCIATED GROUND WATER BASINS.

- (b) Laboratory project, cooperative with Calif. Dept. of Water Resources, California Agric. Experiment Station, and the U. S. Soil Conservation Service.
- (c) Mr. Paul R. Nixon, Agricultural Engineer, P. O. Box E, Lompoc, California.
- (d) Basic and applied research.
- (e) Soil moisture measurements (made with neutron scattering moisture meters to depths of ten to twenty-eight feet) together with measurements of precipitation and other climatological factors are being made on a watershed near Lompoc, California, to determine how much, if any, of the rainfall in certain areas penetrates beyond the root zone, to recharge groundwater. The thirteen sites now being studied represent various cover, soil, and topographic conditions. A study is made of movement of water in various soils to help determine net contribution to ground water recharge by deeply penetrating rainwater. A technique for predicting ground water recharge by deep penetration of rainwater is being developed which will provide probability estimates of seasonal recharge based site conditions and climatological records.
- (g) Downward translocation of moisture has been observed to continue during the dry season following winter precipitation. The magnitude of this migration is predictable and

amount of downward movement of moisture through the root zone can be estimated fairly accurately without the benefit of periodic moisture determinations; provided monthly precipitation data are available and the range of available moisture in the root zone is known.

- (h) "Soil Moisture Interface Effects Upon Readings of Neutron Moisture Probes," by G. P. Lawless, N. A. MacGillivray, and P. R. Nixon. Soil Sci. Soc. Am. Proc. 27:502-507, 1963.

(4851) WATERSHED EVAPOTRANSPIRATION LOSSES IN CENTRAL AND SOUTHERN CALIFORNIA.

- (b) Laboratory project, cooperative with Calif. Dept. of Water Resources, California Agric. Experiment Station, and the U. S. Soil Conservation Service.
- (c) Mr. G. Paul Lawless, Soil Scientist, P. O. Box E, Lompoc, California.
- (d) Experimental and field investigation, basic and applied research.
- (e) Measurements of soil moisture content are being made at 13 neutron scatter metering sites on a watershed near Lompoc, Calif. Soil suction is measured at one site by tensiometers. Precipitation is measured within a complex of four of the soil moisture sites. Outside of the watershed, in a plot (approx. one acre) of perennial ryegrass, soil moisture data are obtained by an electronically weighing lysimeter, neutron scatter meter, tensiometers and moisture blocks. Soil temperature, soil heat flux, drainage from the lysimeter, wind velocity and direction, solar, total hemispherical, and net radiation, albedo, air temperature and humidity are measured in or near the lysimeter. Most of this data is automatically recorded. Data is also obtained from an adjoining USWB class A type climate station, which contains extra instruments consisting of a hygrothermograph, spherical atmometers, and recording rain gage. Purpose of this work is to determine the relationship between evapotranspiration and various climatic, soil, and plant influences as these relationships affect watershed performance with respect to net water yield.
- (g) Much of the available water in the root zones of the native vegetation was quickly used after each dry season started. The lack of available water reduced evapotranspiration rates. It was found that these rates of evapotranspiration correlated to considerable degree with the soil moisture content of the root zones.

(4853) SALINITY BALANCE INVESTIGATION OF CITRUS IRRIGATION ON RESIDUAL SOILS, USING COLORADO RIVER WATER.

- (b) Laboratory project, in cooperation with the U. S. Soil Conservation Service, and Riverside County (California) Flood Control Dist.
- (c) Mr. Sterling Davis, Drainage Engineer, P. O. Box 629, Pomona, California.
- (d) Experimental.
- (e) The salinity of the soil and drainage water from this watershed is compared with total Colorado River water irrigation application plus rainfall to determine the salinity trends within a 1,000 acre watershed planted primarily to citrus orchards. Granodiorite rock underlying these soils minimizes loss of effluent to deep percolation. Bi-annual soil samplings are taken of selected sites within the watershed. Intensive investigations including flow recorders, flumes, and recording rain gages, were activated in May 1961. The program was expanded in 1962 to include sufficiently large flumes to measure winter storm runoff. The project was established as a five-year program.
- (g) Preliminary observations have demonstrated the capabilities of this research technique in securing information on salinity trends

on a watershed-wide basis.

(4854) EFFECT ON TILE DRAINS OF MANGANESE AND IRON SOLUBILITY IN SOILS.

- (b) Laboratory project, in cooperation with the U. S. Soil Conservation Service.
- (c) Mr. L. B. Grass, Soil Scientist, Southwestern Irrigation Field Station, P. O. Box 1339, Brawley, California 92227.
- (d) Experimental.
- (e) A study to determine the ability of various soils to yield ferrous or amanganous ions in drainage effluent under varying conditions of reduction and pH and to develop an index for classifying soils as to their reduction potential. Tile line deposits of manganese and ferric oxide now represent a serious threat to irrigated agriculture, particularly in the Coachella and Imperial Valleys of California. SCS and ARS technicians have collected and forwarded soil samples from 11 locations throughout the United States where this problem has been observed in agricultural drain lines. Apparatus has been set up in the laboratory to subject these reduced conditions.

(5219) WATER DISCHARGE MEASUREMENTS WITH CHEMICAL TRACERS.

- (b) Laboratory project.
- (c) Mr. Lloyd E. Myers, Director, U. S. Water Conservation Laboratory, Route 2, Box 816-A, Tempe, Arizona.
- (d) Experimental; applied research.
- (e) Techniques and equipment for the integrated sample method of water discharge in open channels and in pipelines using fluorescent chemical tracers are being developed.
- (g) A sensitive laboratory fluorometer has been adapted for field use. Preliminary field measurements indicate that uniform mixing of tracer with water flowing in an open channel is difficult to obtain.

(5220) UNSATURATED FLOW CHARACTERISTICS OF AGRICULTURAL SOILS.

- (b) Laboratory project.
- (c) Mr. E. J. Doering, U. S. Salinity Laboratory, P. O. Box 672, Riverside, California.
- (d) Experimental; basic research.
- (e) The objectives are (1) To develop improved techniques (in terms of effort, reliability, and time) for measuring the water transmitting properties of agricultural soils at various matric suction values; and (2) to determine the unsaturated flow properties of a variety of agricultural soils. Diffusion theory and linear flow systems are being utilized.
- (g) The measurement of the unsaturated flow properties of soil is by no means experimentally routine. However, the recent development of apparatus for accurately measuring and recording low rates of liquid flow simplifies the collection of the required outflow data.

(5221) THE ROLE OF SOIL MOISTURE IN SEMIARID RANGELAND HYDROLOGY AND SEDIMENT PRODUCTION.

- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
- (c) Dr. H. A. Schreiber, Soil Scientist, P. O. Box 3926, Tucson, Arizona.
- (d) Experimental; field and laboratory.
- (e) The objectives of this study are: (a) To determine the relation of soil moisture to vegetation and soil characteristics; (b) to determine and evaluate effects of soil moisture and related vegetation conditions on detention, retention, and deep penetration of rainfall; (c) to compare with the naturally occurring moisture regime the effects produced by two imposed moisture regimes on soil and vegetation characteristics relating to the hydrology and sediment production of semiarid rangelands;

(d) to study the effects and interactions with soil moisture of maintaining a higher than natural level of fertility on soil and vegetation characteristics affecting the runoff net water yield, and sediment yields and forage production of semiarid rangeland watersheds.

(5222) PRECIPITATION CHARACTERISTICS AFFECTING HYDROLOGY AND SEDIMENT PRODUCTION OF SMALL AGRICULTURAL WATERSHEDS IN CENTRAL AND SOUTHERN CALIFORNIA.

- (b) Laboratory project, cooperative with Tehachapi Soil Conservation District, and California Agricultural Experiment Station.
- (c) Mr. Paul R. Nixon, Agricultural Engineer, P. O. Box E, Lompoc, Calif. 93438.
- (d) Experimental and field investigations; basic and applied research.
- (e) Objectives of this study are to develop storm time-depth-area relationships of rainfall in Central and Southern California to geographic location in the detail needed for design of flood runoff control works on agricultural watersheds of 400 square miles or less; and to characterize other precipitation parameters relating to the net water yields, flood runoff and sediment production of such watersheds.

(5223) DETERMINING THE EFFECTS ON PHYSICAL WATERSHED MODELING RELATIONSHIPS CAUSED BY MANIPULATING THE PHYSICAL PROPERTIES OF THE FLUID USED IN THE MODEL'S RAINSTORM SIMULATOR.

- (b) Laboratory project, cooperative with the Utah Water Research Laboratory, Utah State University.
- (c) Mr. D. L. Chery, Jr., Hydraulic Engineer, USU Box 229, Logan, Utah.
- (d) Experimental laboratory. Applied research (also for a doctoral thesis).
- (e) To determine the effect on model-prototype relationships of changes in the physical properties of water-chemical mixtures used in a model watershed's rainstorm simulator. Data from the model are compared with records of the prototype watershed (97-acre semiarid watershed near Albuquerque, New Mexico) to ascertain which water-chemical mixtures give the best model verification. The watershed model consists of a 1:175 fiberglass topographical model and an automatically operated rainstorm simulator. In the storm simulator the liquid is applied in several independent subunits by positive displacement pumps driven by variable speed D. C. electric motors. The fluid is distributed evenly over a subarea by equal length polyethylene tubing (0.011 inch ID).

(5224) GROUND WATER AS A FACTOR IN THE WATER BUDGET OF SEMIARID WATERSHEDS.

- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
- (c) Mr. D. E. Wallace, Geologist, P. O. Box 213, Tombstone, Arizona.
- (d) Experimental, field; applied research.
- (e) Objective of the study is to provide information on ground water accretion and movement and aquifer-streamflow relationship as affected by surface and subsurface geologic conditions.
- (g) Research will include: (1) Preparing maps and stratigraphic sections of the watershed and associated areas; (2) collecting cores and samples of the various materials for laboratory analysis; (3) utilizing drilling techniques and sensory methods to determine porosity, permeability, and transmissibility of aquifers and valley material. Pumping tests and tracers will also be utilized in determining flow movement in subsurface strata.

(5225) HYDROLOGIC EFFECTS OF RESEEDING RANGELAND.

- (b) Laboratory project, cooperative with Agricultural Experiment Stations of Arizona and New Mexico, U. S. Soil Conservation Service, local ranch owners.
- (c) Mr. D. R. Kincaid, Research Botanist, P. O. Box 3926, Tucson, Arizona.
- (d) Experimental, field; applied research.
- (e) Treatments comprise combinations of brush removal, soil pitting and reseeded to perennial range grasses. They are applied to replicated 6x12-foot plots, and to drainage areas up to 10 acres. Objective is to investigate effects of a practical range conservation program on yields of water and sediment.
- (g) Mean runoff from eleven storms in the summer of 1963 varied significantly among 24 untreated brush-covered 6x12-foot plots. Soil and vegetation characteristics to which these differences are due are being investigated. Indications are that microrelief, cover of erosion pavement, and cover of vegetation are the most important.
- (5226) DYNAMICS OF WATER AVAILABILITY TO PLANTS.
- (b) Laboratory project.
- (c) Dr. W. R. Gardner, U. S. Salinity Laboratory, P. O. Box 672, Riverside, California.
- (d) Experimental and theoretical; basic research.
- (e) Principles involving uptake of water from soil by plants and subsequent loss to atmosphere are under study. A mathematical model for the soil-plant atmosphere system has been derived. Experiments are conducted in the greenhouse and growth chamber to test the validity of the model.
- (g) The unsaturated conductivity of the soil as well as the soil suction has been shown to be important in governing water uptake by plants. The mathematical model has been extended to provide a quantitative relation between transpiration and soil moisture.
- (h) "The Lower Limit of Water Availability to Plants," W. R. Gardner and R. H. Nieman. Science 143: 1460-62, 1964.
- (5227) EVAPORATION OF WATER FROM FIELD SOILS IN THE PRESENCE OF A WATER TABLE.
- (b) Field project conducted in cooperation with the Southwestern Irrigation Field Station.
- (c) Mr. E. J. Doering, U. S. Salinity Laboratory, P. O. Box 672, Riverside, Calif.
- (d) Experimental; basic research.
- (e) The objectives are (1) To develop simplified but accurate techniques for evaluating evaporative losses from field soils, and (2) to determine the applicability of theory describing evaporation from soils in the presence of a water table to the solution of field problems.
- (f) Completed.
- (g) Both direct (evaporimeter) and indirect (salt accumulation and distribution) methods have been used at a field site in Imperial Valley, California to estimate the actual evaporation rate under essentially steady flow conditions. The two methods produced comparable estimates of the evaporation rate, but greater precision of estimate was achieved by the evaporimeter methods.
- (h) "Salt Accumulation and Salt Distribution as an Indicator of Evaporation from Fallow Soils," by E. J. Doering, R. C. Reeve, and K. C. Stockinger. Soil Sci. 97(5): 312-319, May 1964.
- (5584) SEDIMENT SOURCES AND DELIVERY PROCESSES ON AGRICULTURAL WATERSHEDS.
- (b) Laboratory project in cooperation with Soil Conservation Service.
- (c) Mr. Fred J. Libby, Geologist, P. O. Box E, Lompoc, California.
- (d) Basic and applied research.
- (e) To determine sediment producing characteristics of watershed lands as related to their geology, climate, soils, land use, and treatment; their stream sediment movement and depositional characteristics as related to hydraulic and hydrologic influences; and to develop therefrom methods for prediction of sediment deposition on agricultural flood plain areas and sediment carried out of agricultural watersheds.
- (g) None. Preliminary investigations are being developed.
- (5585) WATER REQUIREMENTS OF LAWN GRASSES.
- (b) Field project in cooperation with the U. S. Navy and the Nevada Agricultural Experiment Station.
- (c) Mr. Rhys Tovey, Research Agricultural Engineer, Agricultural Research Service, P. O. Box 8014 University Station, Reno, Nevada 89507.
- (d) Experimental; applied research.
- (e) 1. Determine minimum water requirements, including depth and frequency of application, to maintain a lawn in a top well dressed condition.
2. Determine minimum water requirements, including frequency and depth of application, to maintain a lawn where it is desirable to reduce maintenance operations to a minimum. Good turf must be maintained that will go dormant during hot seasons and revive when watered by precipitation or irrigation. Study being carried on with nonweighing lysimeters.
- (5586) UNSATURATED FLOW IN GROUND WATER HYDRAULICS.
- (b) Laboratory project.
- (c) Dr. Herman Bouwer, Research Hydraulic Engineer, U. S. Water Conservation Laboratory, Route 2, Box 816-A, Tempe, Arizona.
- (d) Theoretical and experimental, applied research.
- (e) To include the contribution of unsaturated flow to the movement of water below the ground, experimentally determined relationships between hydraulic conductivity and negative water pressure in the soil are simplified to stepfunctions. These functions yield a "critical" pressure head, which is then used as the boundary condition where the flow system is in contact with atmospheric air in the soil.
- (f) Completed.
- (g) The critical pressure head may range from -15 cm of water or more for sands to -100 cm water or less for structureless fine soils. The effect of unsaturated flow is analyzed for systems with mainly horizontal flow, mainly downward flow, and flow through restricting layers underlain by unsaturated material.
- (h) "Unsaturated Flow in Ground Water Hydraulics," Herman Bouwer. J. Hydraulics Div., Proc. Am. Soc. Civ. Eng., 90 No. Hy 5, 121-147, 1964.
- (5587) THEORETICAL ASPECTS OF SEEPAGE FROM OPEN CHANNELS.
- (b) Laboratory project.
- (c) Dr. Herman Bouwer, Research Hydraulic Engineer, U. S. Water Conservation Laboratory, Route 2, Box 816-A, Tempe, Arizona.
- (d) Theoretical, applied research.
- (e) The theoretical effect of channel shape and water depth on seepage was studied with a resistance network analog and analytically for a wide range of soil conditions and positions of the ground water table. The role of unsaturated flow in analyzing seepage flow systems is discussed.
- (f) Completed.
- (g) Dimensionless graphs were constructed showing seepage in relation to water depth in the channel, soil hydraulic conductivity, position of water table at considerable distance from the channel, position of an impermeable layer in the soil, or position of a highly permeable layer in the soil. An equation is developed for the seepage

from channels with a thin, slowly permeable (clogged) layer at the wetted perimeter.

(5588) WATER BUDGET OF EPHEMERAL STREAM CHANNELS IN RELATION TO WATER DYNAMICS, GEOLOGY, AND VEGETATION.

- (b) Field and laboratory project in cooperation with Arizona Agricultural Experiment Station.
- (c) Mr. Hasan K. Qashu, Soil Scientist, and Mr. D. E. Wallace, Geologist, P. O. Box 3926, Tucson, Arizona.
- (d) Laboratory and field research, basic and applied, part of which will be presented as a doctoral dissertation by Mr. Qashu.
- (e) The investigations are aimed at (1) assessment of ground water in local, water tables and development of management practices for sustained supply and improved quality of usable water; and (2) basic research on the relation of temperature variation and fluctuation of the water table to soil moisture movement and evaporation. During the summer rainy season, large proportions of the ephemeral flows are absorbed by the stream channel, resulting in a rise of the surface of the local water table. Many channels with deep alluvial deposits overlying these perched water tables support dense stands of phreatophytes. Evapotranspiration from such areas on the Walnut Gulch Experimental Watershed is being studied by means of both the water budget and the heat balance approach. Amounts of water storage and rates of recharge are determined in the field. Outflow from the area is recorded to the nearest cubic foot, and diurnal fluctuation of the outflow and of the surface of the water table is continuously noted. Using Darcy's Law and a combination of methods for determining soil permeability and hydraulic conductivities, rates of subsurface inflow are computed. By use of a portable seismic unit and 28 observation wells, extent of the aquifer has been determined and an area-depth curve has been prepared.

(5589) RELATION OF SEDIMENTS AND STRATIGRAPHY TO THE HYDROLOGY OF SEMIARID WATERSHEDS.

- (b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations and the U. S. Soil Conservation Service.
- (c) Dr. Philip Seff, Research Geologist, P. O. Box 3926, Tucson, Arizona.
- (d) Experimental, field and laboratory; basic research.
- (e) Sediment collection stations are located at half-mile intervals where good surface exposures exist near the various experimental watersheds. Detailed sample collections of each stratigraphic unit are made and subsequently analyzed in the laboratory. This procedure coupled with a fluvial geomorphic analysis of the existing stream channels provides the necessary data for geologic interpretations, and recognition of changing climatic conditions.
- (g) Information obtained indicates that the major source of sediments is derived from the non-consolidated Lake Cenozoic valley fill deposits on the Walnut Gulch watershed. Heavy mineral analysis is a valuable aid in locating the source areas of sediment. Subsurface water flow is restricted on both the Alamogordo and Walnut Gulch watersheds by high to medium indurated beds of Mesozoic age and older.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
Central States Forest Experiment Station.

Inquiries concerning the following projects should be addressed to R. D. Lane, Director, 111 Old Federal Bldg., Columbus, Ohio 43215.

(3563) SUBSURFACE WATER MANAGEMENT ON NORTHERN

HARDWOOD FOREST AREAS.

- (b) Laboratory project.
- (d) Experimental and field investigations; basic and applied research.
- (e) Movement of subsoil water will be studied in various geologic and soil types to:
 - (1) Develop techniques for quantitatively measuring subsurface water movement from small plots; (2) to learn the effect of artificial rainfall on quantity and timing of subsurface water movement; and (3) to develop a flow equation, including coefficients for the significant variables affecting that flow. This information will aid watershed technicians in making land management decisions on areas that have lots of subsurface stormflow.
- (g) A plot 125 feet long by approximately 18 feet wide was wetted by a sprinkler system. The surface soil of the plot was predominately silt loam textured on a 20 percent slope. The soil surface was well protected by an undisturbed hardwood leaf litter cover. Hardwood roots and root channels were concentrated in the top 24 inches of soil, with extremely dense networks of the surface 11 inches. At a depth range of 32 to 50 inches below the surface a clay loam texture was predominate, in this horizon roots and root hairs were scattered and almost non-existent. Rainfall intensities from the sprinkler system varied from 0.6 to 1.2 inches per hour and storm lengths varied from 90 to 150 minutes. Seepage outflow measurements were made with 8 foot wide troughs inserted in the downslope face of the plot. These troughs were spaced at 0, 24, 32, and 50 inches below the soil surface--the depths corresponding to textural discontinuities. Seepage results from the 1964 fall runs have not been completely analyzed. However, the following preliminary observations were made:
 - (1) For the range of storm intensities used, no surface runoff occurred. The leaf litter protection appears to maintain the permeable condition of the surface soil even after 20 storms in 8 weeks.
 - (2) As in past runs, greatest volumes of seepage flow occurred from the uppermost soil horizon (a coarse textured silt loam overlying a finer textured silt loam). Large quantities of flow appeared to come from root channels and small structural cracks in this surface horizon. This seepage flow peaked shortly after rainfall ended and receded to insignificant quantities in about 6 to 8 hours. Flow from the underlying fine silt loam and clay loam textured horizons was steady and uniform for about 16 to 20 hours following the start of rainfall.
 - (3) No general seepage loss occurred in a lateral direction from the wetted plot soil into the adjacent dry soil; this was confirmed by several batteries of tensiometers installed at the edge of the wetted strip. However, seepage loss from a zone approximately 6 to 8 feet beyond the wetted edge occurred. Because of observation and known soil conditions, it was surmised that this seepage was being channeled off the plot through interconnected biological channels. This has led to the conclusion that there is a critical plot length-width ratio for forest soils having wide-spreading, interconnecting root systems. Future research will be aimed at studying this in more detail with laboratory model studies.The subsurface stormflow plot (with sandy loam texture on a 29 percent slope) used in the 1963 runs was recalibrated with sprinkler runs. Then a 54-inch deep trench was dug across the plot at right angles to the direction of flow and filled with wood shavings. Again, the seepage results have not been fully compiled and analyzed; however, tensiometer and piezometer readings show

the presence of a mounded zone of saturation immediately above the subsoil trench. This indicates a lag in outflow or break in continuity of flow at the sharp air-soil interface. It is felt that this subsoil trenching technique may be a useful tool for temporary detention of subsurface stormflow from shallow soils, such as are found in the Allegheny-Cumberland Plateau. This technique will also be studied in further detail by the use of laboratory models.

(4373) USE OF NUCLEAR RADIATION EQUIPMENT FOR MEASURING FOREST SOIL MOISTURE AND DENSITY.

- (b) Laboratory project.
- (d) Experimental and field investigations; basic and applied research.
- (e) Some newly developed equipment, operating on the principle of nuclear radiation, facilitates the measurement of soil moisture and the soil's closely allied property--bulk density. We now have a five-piece set of this nuclear radiation equipment. We are investigating principles that will guide us in the use of this equipment.
- (f) Completed.
- (h) "Characteristics of a Commercially-Available, Surface-Moisture, Nuclear Probe," by Richard B. Marston. Bulletin of the International Association of Scientific Hydrology, IX, No. 2, pp. 80-89, 1964. Copies available upon request to Station Director.

(4752) THE CHARACTERISTICS OF A CONIFEROUS PLANTATION THAT ARE MOST CLOSELY RELATED TO TREE GROWTH AND TO WATER AVAILABLE FOR STREAMFLOW.

- (b) Laboratory project.
- (d) Experimental and field investigations; basic and applied research.
- (e) This is an intensive soil-moisture study initiated to discover some basic tree stand characteristics that are closely related to tree growth and to water available for stream flow and to develop guidelines for field use in managing forest plantations to obtain optimum production of wood and water.
- (g) In the first growing season after cutting, treatments have opened plantation spacing, but soil moisture and growth results have not yet been analyzed. The wood removed in plantation thinnings was chipped and scattered over the study plots before the start of the 1964 growing season.

(4753) FOREST RESTORATION AND WATERSHED MANAGEMENT ON SURFACE MINED AREAS IN THE APPALACHIAN COAL FIELDS.

- (b) Laboratory project.
- (d) Experimental and field investigations; basic and applied research.
- (e) Surface runoff on spoil banks, freshly formed during strip mining in the Appalachian coal fields, has a high soil erosion and sediment transport potential. This seriously affects water quality and has other deleterious effects on watersheds in which coal is harvested. It is highly desirable to establish a vegetative cover as quickly as possible after mining disturbance in order to minimize erosion and maintain water quality. The purpose of this project is to (1) develop practical methods of reducing damage to watershed values during surface mining operations and (2) find feasible ways to restore mined areas to productive forest uses. Studies by individual scientists are divided among five disciplines including (1) Spoil Placement, (2) Soil Chemistry, (3) Haul Roads, (4) Revegetation, and (5) Hydrology. General hydrology studies recently started include (1) A study of stormflow and sediment yield from stripmined terraces; (2) a study of stormflow and sediment yield from outcrops of stripmined soil banks; and (3) a study of the hydrology of ponds

originating on stripmined lands.

In these studies a number of small San Dimas flumes have been installed to measure storm runoff from a number of terrace and outslope drainages. In the pond hydrology study a number of stilling wells and recorders have been installed on ponds. Rainage networks have been installed to cover each sample drainage area.

- (g) The program to develop revegetation techniques which will protect and stabilize the disturbed areas was accelerated last year. Early results are encouraging but inconclusive, because the inherent chemical and physical variability of spoils material causes inconsistencies which will require intensive study to explain. However, after two growing seasons black locust planted at a 4 by 18 foot spacing in contour rows promises to provide belts of vegetation on the steep outcrops which can stabilize the banks. As these trees develop, they may affect the micro-environment and create conditions more favorable for the establishment and growth of other vegetation. Trials of quick cover species were continued with some success. Encouraging results were obtained with annuals, Blanco lupine and Balbo rye, and the perennials tall fescue and weeping lovegrass. Density of these ground covers was quite variable even on small areas due to physical and chemical characteristics of the banks. Physical properties affecting seedlings germination and growth were the erosive nature of the spoil surface and a tendency of the surface to crust over as it dries out. Chemical properties which may influence revegetation practices are: acidity, generally below pH 5; high concentration of soluble salts; and the pressure of high concentrations of available iron, sulphur, aluminum and manganese.
- (h) "Predicting Outcrops of Spoil Banks," Robert F. May. Central States Forest Expt. Sta. Research Note CS-15, 4 pp. 1963. "Surface-Mine Reclamation: Continuing Research Challenge," Robert F. May. Coal Age 69(3): 98-101, 1964.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Inquires concerning projects should be addressed to Mr. Joseph F. Pechanec, Director, Intermountain Forest and Range Experiment Station, Ogden, Utah.

(5295) SNOWMELT FLOOD AND SEDIMENT REDUCTION.

- (b) Laboratory project.
- (d) Experimental and field investigations; basic and applied research.
- (e) To determine quantitative relations of forest characteristics and timber harvesting procedures on snow accumulation and melt, streamflow peaks, sedimentation, and improved timing of water yields.
- (g) A flow meter, consisting of a small Parshall flume and an attached water-level recorder, has been developed to record groundwater seepage continuously from road cut banks. For low flow rates, inserts in the flume throat convert the Parshall flume to an orifice-type flow meter. The flow meter can easily register changes in groundwater discharge caused by fluctuations in evapotranspiration. A major problem in watershed management is the design of proper drainage facilities on logging roads to prevent erosion and deterioration of streamflow. An important component of the problem is the volume of drainage water emanating from roads. Study roads are located at the 6400-foot elevation in the Engelmann spruce-fir type. On the inside ditches, 12 Parshall flumes collect and provide measurement of seepage flow from 100-foot sections of the cut

bank of the road. Data on the amount of seepage flow during the period, June 5-29, 1964, show that the hydrograph for the road in the forested block is generally subdued and less abrupt than the one representing the clear-cut block. In addition, the seepage-flow peaks on the hydrograph for the forested area are smaller than those on the hydrograph for the clear-cut block. Usually the daily upsurge of seepage flow--and by inference, snowmelt--begins and ends sooner in the clear-cut block, probably because snowmelt is dependent primarily upon direct solar radiation that begins as soon as the sun's rays reach the snowpack. Snowmelt in the forested stand depends more upon longwave radiation. Tree cover distributes this radiation more evenly throughout the day and helps to keep the environment warmer into the night. From the date the snowpack disappeared (June 24 in the clear cut and June 29 in the forest), both seepage hydrographs began the long summer decline interrupted only by rain showers. Mapping of the subsurface configuration of bedrock and the presence of the water table has been completed in the six treatment blocks on the road hydrology study area. A portable NED Geochrome seismograph was used to determine bedrock depth under the 24-acre study area with a quartz monzonite bedrock. A problem arose when certain portions of the area remained saturated long after the remainder of the area dried out. We surmised the cause was a relatively shallow depth to bedrock which forced groundwater to the surface to create the marshy area. This became particularly evident after clear cutting the spruce-fir stand. One hundred-foot traverses were laid out over the study area wherever the terrain indicated the likelihood of change in bedrock configuration. Traverses were also located on all sides of the marsh to pinpoint any bedrock "dikes" or ridges. Two 2-man crews completed a forward and reverse run on 36 seismic traverses, making a total of 72 individual traverses. Results of this work showed that the average seismic velocities, V_1 , V_2 , and V_3 were 1612, 4884, and 9629 feet per second, respectively. Also, the average D_1 (depth to V_2 layer or water table) was 7.5 feet and the average D_2 (depth to bedrock) was 25.7 feet. The V_1 layer represents the unsaturated soil layer and the seismic velocity increased to V_2 at the water table. The presence of the water table at about 7.5 feet was verified by measurements taken in numerous observation wells within the study area. A V_3 value of 9,000 to 10,000 feet per second is reasonable for this type of bedrock. Seismic traverses uphill from the marsh area showed depth to bedrock in excess of 33 feet. This is about the maximum point of sensitivity in picking up seismic waves generated by a sharp sledge-hammer blow on a metal plate. For measuring greater depths, blasting powder is used. Near the upper edge of the marsh, bedrock depth decreased to 29 feet, and below the marsh the bedrock depth ranged from 11 to 15 feet. Slope distance from the upper to the lower edge of the marsh was 300 feet. We concluded that this decreasing depth to bedrock did cause groundwater to seep out and create a marshy area. A multiple regression of soil-moisture data taken at randomly located points over the 24-acre plot showed that bedrock depth was a statistically significant variable which could be used to help predict soil moisture; i.e., as the depth to bedrock decreased, soil moisture increased.

- (h) "Flow Meter for Measuring Groundwater Seepage from Road Cuts," Edward R. Burroughs, Jr. U. S. Dept. Agr., Forest Serv., Intermountain Forest and Range Experiment Station Res. Note INT-11, 1964, 4 pp. illus. "Guides for Controlling Sediment from Secondary Logging Roads," Paul E. Packer and

George F. Christensen. U. S. Dept. Agr., Forest Serv., INT and Northern Region Misc. Pub., 1964, 42 pp., illus.

- (5296) SOILS STABILIZATION IN RELATION TO LOGGING ON STEEP TIMBERED SLOPES IN THE NORTHERN ROCKY MOUNTAINS.
- (b) Laboratory project.
 - (d) Experimental and field investigations; basic and applied research.
 - (e) To identify and quantify the interrelations of soil, water, and vegetation to soil stability; to determine mechanical and vegetation requirements for stabilizing soil; and to determine effects of timber harvesting and roadbuilding on soil movement and water yield.
 - (g) Stability of fill slopes of newly constructed roads may be increased by establishing a good grass cover. In many instances, however, a grass cover is difficult to establish because the broadcast seed roll off the crusted soil of the fill. Loss of seed is particularly severe when such firm, rounded seeds as yellow sweetclover or cereal rye are used. Laboratory tests show that seed retention may be increased markedly by seeding upon a hay mulch, wet or dry paper netting, a wet soil surface, or on a "pockmarked" soil surface. Two study compartments were established on very steep forested terrian in central Idaho. The purpose of the study is to compare soil erosion caused by jammer and high-lead logging methods. Erosion is measured both on small watersheds and on 1/100-acre plots. One compartment ("Deep Creek") was established in 1960, and the following year two roads were built into the Jammer area but not into the high-lead area. Both areas were then logged in 1962. Prior to road construction, measurable erosion from both areas was negligible. As a general rule, soil movement in this area takes place mostly during the spring runoff period. This is illustrated by figures for the high-lead area where, as the aftermath of logging activities, only 3 TSM (tons per square mile) eroded during the 7-month cold season in contrast to 25 TSM during the few weeks of the spring thaw. Where only tree-removing activities occurred, soil damage was negligible as evidenced by the zero figure of the high lead area. In contrast, damage was high (552 TSM) in the presence of raw fills on newly built roads. Very little information is available about runoff and erosion from small forested watersheds in central Idaho. Although these watersheds are primary sources of water, little is known about their hydrology, and nothing is known about the consequences of logging. As a first step in bridging this hiatus in knowledge, we began (toward the end of 1962) taking simultaneous stream measurements from two contiguous watersheds. In correlating streamflow with the amount of precipitation falling on these watersheds, runoff represents only one-third of the total precipitation, and evaporation and transpiration utilize fully two-thirds of total annual precipitation. Appropriate field instruments have yet to be devised for the continuous measurement of sediment movement. Nevertheless, our studies lead us to believe that sediment movement is best understood by its seasonal occurrence. During the summer and early fall when streamflow is low, sediment is pushed or rolled along the streambed. In Circle End Creek, daily movement during this period amounted to only 0.003 ton per square mile. In contrast during the early spring, rapidly rising streams flush out accumulated sediment. During this period, daily soil movement in Tailholt Creek was 0.15 ton per

square mile.

Finally, we also found that the two contiguous watersheds (Tailholt and Circle End) react very similarly to any given storm. If, as the result of a storm, streamflow rises in one watershed, we can predict very accurately the rise in the adjacent stream. If we know the time required for one creek to peak, we can accurately predict the time for the other.

- (h) "Effect of Severe Rainstorms on Insloped and Outsloped Roads, H. F. Haupt, H. C. Rickard, and L. E. Finn. U. S. Dept. Agr., Forest Serv., Intermountain Forest and Range Experiment Station Res. Note INT-1, 1963, 8 pp., illus.
- "Laboratory Methods for Determining the Downward Movement of Seed on Road Fills," H. F. Haupt and W. J. Kidd, Jr. U. S. Dept. Agr., Forest Serv., Intermountain Forest and Range Experiment Station Res. Note INT-2, 1963, 7 pp. illus.
- (5297) WATERSHED PROTECTION REQUIREMENTS AND REHABILITATION MEASURES FOR THE REDUCTION OF FLOOD RUNOFF, EROSION, AND SEDIMENT FROM DETERIORATED FOREST AND RANGELANDS.
- (b) Laboratory project.
- (d) Experimental and field investigations; basic and applied research.
- (e) To relate soil and vegetation characteristics to infiltration, overland and subsurface flow, and soil erosion; to develop flood and erosion hazard criteria and protection requirements for deteriorated rangeland; and to determine effects of watershed rehabilitation on erosion hazard and flood potential.
- (g) A recent study on a grass-forb subalpine range in central Utah showed that infiltration capacity, as measured by the inches of water retained on infiltrometer plots during simulated rainfall of 50-minutes duration, is influenced primarily by bulk density and noncapillary porosity of the surface 4 inches of soil and secondarily, by density of protective cover afforded by plants, litter, and stone. The study also shows that soil stability, as measured by the amounts of soil eroded from the infiltrometer plots, is influenced primarily by the density of protective cover and, secondarily, by soil-bulk density.
- The past summer we began a study designed to investigate the infiltration and sedimentation characteristics of newly constructed contour trenches in soils and fractured underlying parent materials on Davis County Experimental Watershed. The soils are derived from pre-Cambrian sediments that have been metamorphosed to produce quartzites, gneisses, and schists. Specific objectives of the study are to determine: (1) Infiltration rate characteristics of water ponded in contour trenches, (a) during the first year of trench installation, and (b) in subsequent years. (2) Whether there is differential permeability between the cut-slope and fillslope portions of contour trenches. (3) Which of several soil and vegetation factors affect first-year infiltration rates, changes in these rates with time, and changes in differential permeability between cut and fill portions of the trenches. (4) The sources of and quantities of sediment moving into contour trenches during both the summer and the spring runoff seasons. (5) Which of several soil, vegetation, and topographic factors affect the amount of sediment moving into contour trenches. (6) The volume (storage capacity) changes of contour trenches with time as affected by: (a) subsidence or settling of trench fill sections, and (b) sediment deposition in trench bottoms. The volumes of 10-foot sections of trench are being determined by filling plastic-lined sections with water measured through a sensitive flow meter and calibrated to manometers for depth. Infiltration rates

are being measured by slitting and removing the plastic liners and measuring the changes in water depth on the manometers with time. The effect of temperature on the mobility of water in unsaturated soil is an important consideration in virtually all studies involving soil-moisture movement. Whether we are interested in infiltration, soil-moisture depletion, deep percolation or other unsaturated soil-moisture flow processes, the influence of temperature should be recognized. It has generally been assumed that variation of soil-moisture conductivity with temperature could be accounted for by corrections based on published values of viscosity of free water. However, theoretical considerations suggest viscosity of water near soil-water interfaces is greater than that of free water. Measurements of self-diffusion of water in unsaturated soil systems tend to confirm this hypothesis.

In general, the stronger the bonds between molecules in a liquid the greater is the effect of temperature changes on the fluid properties of that liquid. Soil water, being subject to adsorptive forces of the soil solids, can be expected to exhibit greater temperature dependence of flow properties than does free water. In saturated soil, especially one with large pores, a large portion of the water is not subject to strong attractive forces and the effects of temperature may not be appreciably greater than for free water. In unsaturated soil, the forces between water molecules are greater than they are in free water, and these forces can be expected to increase as soil-moisture tension increases. As a result, the effects of temperature on fluid properties would be greater in unsaturated soil than in saturated soil, and a temperature correction based on published free-water viscosity values would be inadequate.

Soil physicists have recently borrowed the activation energy concept from chemical kinetics in order to measure strengths of bonds between soil water molecules. In its simplest form, activation energy may be defined by the Arrhenius equation:

$$E^* = RT^2 \frac{d \ln K}{dT}$$

in which E^* is the Arrhenius activation energy, K is a chemical rate constant or any other accurate parameter of molecular reaction, R is the universal gas constant, and T is absolute temperature. The temperature dependence of a large number of simple chemical reaction rates can be characterized by equations of this type. E^* is the energy barrier which must be surmounted for a reaction to take place. In the case of evaporation, it is energy of vaporization. In the case of viscous flow, it is N times the average energy required for a molecule to move out of one quasi-equilibrium position far enough to be pulled into another quasi-equilibrium position, N being the number of molecules in a mole. If bond energies between molecules of water in soil systems are the same as those of free water, a temperature correction based on the viscosity of free water would be satisfactory, and the corresponding activation energy would be 4.16 kilocalories per mole at 20°C.

In the laboratory we measured capillary-conductivity coefficients of two clay loam soils and a silt loam at 12°, 20°, 30°, and 40°C. over a range of moisture contents corresponding to moisture tensions varying from 0.05 to 0.5 atmosphere. We calculated activation energies using the Arrhenius equation with conductivity coefficients as rate constants. Averaged over the range of moisture contents studied, the activation energies in kilocalories per mole

were: 12.7 ± 1.0 for one clay loam, 14.9 ± 1.6 for the other clay loam, and 7.8 ± 0.4 for the silt loam. This means that average bond strengths in soil water under the experimental conditions were two to three times as great as in free water. This, in turn, indicates that higher viscosity of adsorbed water materially influences moisture flow in the 0.05 to 0.5 atmosphere tension range.

According to available evidence, a simple correction based on the temperature dependence of free-water viscosity will usually account for temperature-induced changes in soil-moisture diffusivity at the low-moisture tensions at which the bulk of liquid flow occurs during infiltration. However, at greater tensions, such as exist at field capacity, soil-moisture conductivity appears to be much more temperature-dependent than is free-water viscosity. The influence of temperature on moisture conductivity in this moisture range cannot be satisfactorily accounted for by a simple viscosity correction. No reliable alternative can be suggested at this time; further study is required to develop accurate correction factors for any soils other than the ones tested in this experiment. The results of this experiment emphasize the need for careful temperature regulation in studies involving liquid movement in soils in the field moisture content range.

- (h) "Soil Stability Requirements for the Gallatin Elk Winter Range," Paul E. Packer. Jour. of Wildlife Mgmt. 1963, 27:401-410.
- "Effects of Trampling on Soil and Vegetation," Hudson G. Reynolds, Paul E. Packer. Range Research Methods--a Symposium, Denver, Colo., May 1962. Misc. Pub. No. 940, 1963, U. S. Dept. Agr., Forest Service.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
Lake States Forest Experiment Station.

Inquiries concerning the following projects should be addressed to the Director, Lake States Forest Experiment Station, St. Paul Campus, University of Minnesota, St. Paul, Minn., 55101, unless indicated otherwise for a specific project.

- (3887) WATERSHED MANAGEMENT RESEARCH IN NORTHERN MINNESOTA.
 - (b) Laboratory project.
 - (d) Experimental and field investigations; basic and applied research.
 - (e) Tests the influence of forested bogs on streamflow and groundwater behavior. The five major studies reported for 1963 are still underway. In studies of forest bog hydrology, an additional bog has been instrumented with an H-flume bringing the total number of bogs under instrumentation to 6 with a total of 6 recording wells, 55 nonrecording wells, and thirteen 10-foot-diameter bottomless lysimeters. This sixth bog is intended for studies in manipulation of water level to determine its effect on evapotranspiration.
 - (g) A preliminary analysis has been made for several warm season evapotranspiration losses from May 1 to October 1 for two bogs by two methods. The first involved precipitation, runoff, and water table levels in the bog used as an indicator of storage changes. This method was then compared with potential evapotranspiration computed by the Thornthwaite method from available temperature records taken near the two bogs. For any one 5-month season, there was rather close agreement between the two methods with the maximum difference being 1.20 inches and the minimum being 0.13 inch. For combined evapotranspiration, values were 18.46 and 18.57 inches respectively. For individual, monthly, or similar

short-term periods, the differences expressed percentage-wise are considerably larger.

Another aspect of these bog studies involves water-movement rates through laboratory cores and in situ using a piezometer and tube method tests. These indicate a substantial difference by the two methods with the field results preferred over the laboratory results obtained with cores. Another aspect of the bog hydrology studies involved a comparison of predicted rise of water based on laboratory measurements of specific yields from several peats and actual rise of water table obtained in stage recorders. The results based on 38 growing-season storm periods during 1961, 1962, and 1963 indicate a correlation coefficient (r) of 0.96 and show that the slope of the line was very nearly 1.0. The storms involved ranged from 0.04 to 1.69 inches, and the range of water table elevations was 0.67 foot.

- (h) "What's New in Wetland Hydrology," Roger R. Bay and Ralph A. Klawitter. Proc. Soc. Amer. Foresters, 175-177, 1963.
- "Importance of Volumetric Expression of Water Contents of Organic Soils," D. H. Boelter and G. R. Blake. Soil Sci. Soc. Amer. Proc. 28(2): 176-178, 1964.
- "Water Storage Characteristics of Several Peats in Situ," D. H. Boelter. Soil Sci. Soc. Amer. Proc. 28(3): 433-435, 1964.
- "The Water of the Lake States - a Vital and Critical Resource," Sidney Weitzman, The Northern Logger. 12(11): 8-9, 32-33, 37, 1964.
- (3889) WATERSHED MANAGEMENT RESEARCH IN THE DRIFTLESS AREA OF SOUTHWESTERN WISCONSIN.
 - (b) Laboratory project, with some aspects in cooperation with Wisconsin Conservation Dept.
 - (d) Field investigations; basic and applied research.
 - (e) Major emphasis is given to methods of controlling runoff and erosion, including gully stabilization through reforestation, and other land-use treatments. To date, a total of 37 water-measuring devices have been installed on small watersheds, on small runoff plots, or at springs. Included are 3 V-notch weirs, 4 San Dimas flumes, and 30 H-flumes. Of the above devices, three are at springs with permanent flow. To further probe the usefulness of the forested zone on the steeper hillsides, additional research is now underway to estimate where channel absorption is best in gullies and to determine if this can be correlated with a specific underlying geologic stratum. This will involve a series of low earth dams each with a stage recorder which will show rate of recession of water behind each structure. Also in process of installation are trials of water diversion and water spreading to intercept runoff water before it gets into a gully and to spread it thinly against a series of logs placed on the contour or into a series of several small catchment basins in which it is hoped to achieve some recharge to ground water.
 - (g) Further runoff studies of eight dual-use watersheds (i.e., partly in farmland on gently sloping ridgetops and with timber cover on the steeper land below) indicate that at four of the eight valley flumes there has been no runoff to date since installation 2 to 3 years ago, even from snowmelt and from a 5-inch rain. At two other flumes there was runoff only once--during snowmelt. Only one of the eight watersheds yielded a number of flows at valley flumes. These results imply substantial absorption of runoff from upland farmland by forested land lying below it. Apparently there is considerable infiltration into the bottom of the gullies within the forested zone. Some additional wells drilled near a spring involving 29 wells 20 to 100 feet deep bolstered a conclusion reported last year

that there are ground-water highs under topographically low areas (natural drainage ways) and vice versa. However, periodic measurement of water levels in these wells over winter showed no consistent pattern--with some rising, some falling, and others staying about the same. In the past year, a study was made of some file records and reports on a series of lysimeters installed in 1935 near La Crosse, Wis. Each tank was 10 by 20 feet in dimensions and 4 feet deep, filled with monoliths of loessal Fayette silt loam, and capped with an 8-inch layer of topsoil. Various tree, grass, and grain crops were involved. Results indicated highest percolate yield with mulched hardwoods and the level from annual crops. More details on the study are given in the two publications listed below.

- (h) "Water Yield and Soil Loss from Soil-Block Lysimeters Planted to Small Trees and Other Crops," Richard S. Sartz, U.S. Forest Serv., Res. Paper LS-6, 23 pp. 1963.
"Duration of Percolation From a Loess Soil," Richard S. Sartz, U.S. Forest Serv., Res. Note LS-40, 2 pp 1964.

(3890) WATERSHED MANAGEMENT RESEARCH IN LOWER MICHIGAN.

- (b) Laboratory project.
(d) Field investigation; basic and applied research.
(e) Two major projects have been undertaken to date: 1) A major study is designed to determine the hydrology of ground-water recharge and consumption in deep sandy soils of the Udell Hills area in Michigan. Installations to date include a series of 114 ground-water wells in deep morainal areas and adjoining outwash plains; of these, 8 have automatic recorders. After the calibration period, the effect of cover manipulation -- especially plantation establishment and harvesting methods -- on ground-water recharge and use will be established. (2) A second major study is concerned with streambank stabilization and the sediment problem in streams flowing through these sandy areas. Major objectives of this study are (a) to determine the influence of land use upon sediment production, and (b) to evaluate the effect of streambank stabilization measures upon suspended sediment loads. A total of 20 sampling stations have been established on 11 streams. A new aspect of the study on streambank stabilization includes tests of rock riprap at or near the waterline and planting brush species above it. Upperbank treatments also include seeding and fertilizing plus various chemical mulch applications.
(g) An analysis was made of several aspects of ground-water exploration with seismic refraction and electrical resistivity methods. The analysis showed these things: (1) There is a clear separation between seismic velocities in saturated and unsaturated sands; (2) unsaturated clay tills were not distinguishable from saturated sands; (3) areas with till cap over unsaturated sands are not promising for seismic methods of exploration; (4) where till cap occurred, the electrical resistivity method supplied the only useful data on depth to the saturated layer; (5) saturated clay could not be distinguished from saturated sands by this method; (6) with control wells at one-half mile spacing and reasonably straight slopes, seismic methods can predict water table depths within 1 or 2 feet; and by resistivity methods they were predicted within 5 feet, in sandy drift up to 150 feet in depth. A second aspect of the research here involved calculation of evapotranspiration for 2 water years 1961-62 and 1962-63 in different conditions of cover type and water table depth in sandy soils. These showed a range from 16.14 inches to 21.85 inches with somewhat greater losses in two conifer types than in broadleaf types,

apparently due to a longer evapotranspiration period (especially spring and autumn) and greater evaporation from snow, including that from snow intercepted by crowns. Net recharge to ground water is inversely related to gross evapotranspiration. A third facet of the study in the Lower Peninsula of Michigan involved a calculation of mean sediment yield in streams in sandy land with steep eroding banks and as affected by land use. Cultivated land yielded 2,200 pounds of sediment per square mile per day; pasture land, 1,800 pounds; and forest lands, 360 pounds. It is presumed complete exclusion of livestock from eroding banks and use of riprap will reduce the sediment yield. This idea is now under trial on the Tobacco River.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
Northeastern Forest Experiment Station.

Inquiries concerning the following projects should be addressed to Dr. Ralph W. Marquis, Director, Northeastern Forest Experiment Station, 102 Motors Avenue, Upper Darby, Pennsylvania 19082.

(1188) WATERSHED MANAGEMENT RESEARCH, FERNOW EXPERIMENTAL FOREST, WEST VIRGINIA.

- (b) Laboratory project.
(d) Field investigation; basic and applied research.
(e) Studies were started in 1951 on the Fernow Experimental Forest, Tucker County, W. Va., to determine the effect of different levels of cutting practices, different logging methods, and different forest uses upon water quantity and quality. Nine watersheds have been equipped with streamgaging stations and rain-gages.
(g) A commercial clearcutting was made on a 74-acre gaged watershed; skidroads were loggers' choice--without limitations as to grade or provisions for drainage. After-logging infiltration rates in the watershed remained well above maximum rainfall intensities except on portions of the skidroads. Overland flow occurred only from the skidroads; it resulted from the combination of rain directly on the skidroads and interception of subsurface flow by the road cuts. Increased storm runoff in the growing seasons--up to a maximum of about 1/2 area-inch in any one storm--was largely the result of decreases in field-moisture deficiency rather than changes in the proportions of surface and subsurface flow. A method was developed for approximating total soil-moisture storage capacity of an experimental watershed from precipitation and stream-flow records. Precipitation minus runoff--in selected periods when ample precipitation follows a dry spell--provides the estimate of soil-moisture storage capacity. The method is illustrated with data from the Fernow Experimental Forest and is applied to two other watersheds in the Northeast. Limitations of the method are also discussed.
(h) "Water Quality and Soil Erosion as Affected by Logging in Steep Terrain" J. W. Hornbeck and K. G. Reinhart. Jour. Soil and Water Conserv. 19: 23-27, illus. 1964.
"Approximating Soil-Moisture Storage in Experimental Watersheds by Means of Precipitation and Streamflow Records," K. G. Reinhart. Soil Sc. Soc. Amer. Proc. 28: 575-578, illus.
"Effect of a Commercial Clearcutting in West Virginia on Overland Flow and Storm Runoff," Kenneth G. Reinhart. Jour. Forestry 62: 167-171, illus.
"Stream-Gaging Stations for Research on Small Watersheds," K. G. Reinhart and Robert S. Pierce. U. S. Dept. Agr. Agr. Handb. 268. 37 pp., illus. 1964.

(2419) WATERSHED MANAGEMENT RESEARCH, HUBBARD BROOK
EXPERIMENTAL FOREST, NEW HAMPSHIRE.

- (b) Laboratory project.
- (d) Field investigation; basic and applied research.
- (e) The objective is to determine the effect of forest type, condition, and treatment on quantity and quality of streamflow. Studies are conducted in plots and experimental watersheds on the 7500-acre experimental forest in the White Mountains at West Thornton, New Hampshire. Seven weirs have been built and climatic stations established.

(4756) WATERSHED MANAGEMENT RESEARCH, SYRACUSE
UNIVERSITY, NEW YORK.

- (b) Laboratory project, in cooperation with the State University College of Forestry at Syracuse University, Syracuse, New York.
- (d) Field investigation; basic and applied research.
- (e) This cooperative project was started in 1961 to determine quantitative relationships of forest types and stand conditions to the amount, timing, and quality of streamflow in the Adirondacks, the glaciated Appalachian Plateau, and the Catskills.
- (g) Accumulated figures of snow melt for open, hardwood, and conifer areas on the Tully Forest for the winter 1961-62 were applied to the cover types of the Albright Creek (largely open) and Shackham Brook (largely forested) Watersheds and related to their actual runoff. After March 28 little snow remained on Albright and peak rates were generated from Shackham. Results suggest again that a desirable pattern of land use on the Allegheny Plateau, for improved streamflow regimen, would be a combination of open and reforested lands.
- (h) "Snowmelt Studies on the Tully Forest in Central New York," Donald R. Satterlund and Arthur R. Eschner. Eastern Snow Conf. Proc. 1964: 14-22, illus.

(5323) WATERSHED MANAGEMENT RESEARCH, NEW LISBON,
NEW JERSEY.

- (b) Laboratory project in cooperation with: (1) the School of Forestry, Pennsylvania State University and the Pennsylvania Dept. of Forests and Waters; (2) Baltimore (Md.) Bureau of Water Supply; and (3) Division of Water Supply of the City of Newark, N. J.
- (d) Field investigation; basic and applied research.
- (e) At Pennsylvania State University a cooperative study was started in 1957 to determine the effect of forest cover and treatment on quantity and quality of streamflow in the oak-hickory type in Pennsylvania, and to study associated and basic soil-water relationships. Six experimental watersheds have been selected, weirs have been constructed, and climatic stations established.
At Baltimore, Md. a cooperative study started in 1958 to determine effect of growth of loblolly and white pine in plantations on streamflow, and to compare streamflow from watersheds in conifer plantations with streamflow from a hardwood-forest watershed. Streamflow of three experimental watersheds is being measured and a climatic station has been established. An inexpensive weir to gage small streams was built of wood and lined with a sheet of vinyl film. The cost was about \$850 and the weir is expected to last 5 to 10 years without repair.
At Newark, N. J. a cooperative study to determine the influence of selected treatments of forested municipal watersheds on water supply. Weirs on 3 experimental watersheds were built in the fall of 1958 and stream gaging and climatic measurements were started in the spring of 1959.
- (g) In a single-watershed calibration of the experimental Dilldown Watershed in Pennsylvania, equations were developed for predicting

annual runoff and monthly water loss or runoff. The basic relationships were developed from streamflow, climatic groundwater, and soil-moisture records, but the final equations were expressed in terms of runoff and climatic variables only. Standard errors of estimate were well below the minimum change in yield considered significant, namely, 10 percent of the annual or monthly runoff.

Trough gages used to measure throughfall under vegetation and rainfall in the open at the Dilldown Watershed in Pennsylvania gave deficient catches due to rainfall splashing out of the trough. The deficiency was inversely related to the slope of the trough. Correction regressions were computed. A 90° and 120° V-shaped trough may give a better catch than the semicircular, used in this study for raindrops would not bounce vertically from the steep sides. Recording instruments that have a clock-driven chart drum and pen-arm assembly may be converted to a wind-movement recorder with a \$5 expenditure for an electromagnet, dry cells, and assorted small hardware. Dry cells are connected in series with the anemometer contacts and the electromagnet. Closure of contacts activate the magnet, a counterweight, and the pen-arm. If no instrument is available the necessary parts may be purchased for about \$80.

A relationship between bulk density and soil depth plus stone content was developed from Lakeland sand and Lakehurst sand in the Coastal Plain of New Jersey. From this, bulk density was estimated for each soil-moisture sample in five 1-foot layers. Moisture content by weight for each 1-foot layer was converted to moisture content by volume by applying the respective estimated bulk densities. Variations within and between the relatively close-spaced plots are presented for estimated bulk density and moisture content by volume for each of the 1-foot layers. Vegetation along the stream channels of two small forested watersheds was sprayed with 2, 4, 5-T with a mistblower to determine the extent of streamflow contamination. Water samples were taken just above and below the treatment area and 1 mile downstream immediately after spraying, 4 hours later, and for several days thereafter. Samples taken just below the treated area, within 4 hours of treatment, and later after a 1-inch rain were contaminated. There was no contamination one mile downstream.

- (h) "Calibrating a Watershed by Using Climatic Data", Irvin C. Reigner. U. S. Forest Serv. Res. Paper NE-15, 45 pp., illus. Northeast. Forest Expt. Station.
- "Evaluation of the Trough-Type Rain Gage", Irvin C. Reigner. U. S. Forest Serv. Res. Note NE-20, 4 pp. Northeast. Forest Expt. Station.
- "How to Make a Wind-Movement Recorder From any Spare Drum-Type Recorder", I. C. Reigner. U. S. Forest Serv. Res. Note NE-21. Northeast Forest Expt. Station.
- "Variations in Bulk Density and Moisture Content Within Two New Jersey Coastal Plain Soils, Lakeland and Lakehurst Sands," I. C. Reigner and John J. Phillips. Soil Sci. Soc. Amer. Proc. 28: 287-289.
- "Control of Riparian Vegetation with Phenoxy Herbicides and the Effect on Streamflow Quality", I. C. Reigner, W. E. Sopper, and R. R. Johnson. Northeast. Weed Control Conf. Proc. 18: 563-570.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
Northern Forest Experiment Station.

Inquiries concerning the following project should be addressed to Mr. Richard M. Hurd, Director, Northern Forest Experiment Station, 210 Admiral Way, Juneau, Alaska 99801.

(2654) EFFECT OF LOGGING ON PHYSICAL CHARACTERISTICS

OF SALMON STREAMS IN SOUTHEAST ALASKA.

- (b) Laboratory.
- (d) Field investigation, applied.
- (e) This work is concerned with the relationships between salmon spawning streams and timber harvesting in Southeast Alaska. Work is concentrated on 3 streams lying 40 miles west of Ketchikan. Two of the watersheds have been logged. The third watershed will remain unlogged. Study is concentrated on factors that can exert a major influence on pink and chum salmon development and survival in streams in a logged watershed. During 1964 stream discharge and stream temperature measurements were obtained.
- (f) Study discontinued in original form; stream discharge and water temperature measurements continuing. Data analysis continuing.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
Pacific Northwest Forest and Range Expt. Station.

Inquiries concerning the following projects should be addressed to Mr. Philip A. Briegleb, Director, Pacific Northwest Forest and Range Expt. Sta., P. O. Box 5141, Portland, Oregon, 97208.

(4757) WATER YIELD AND EROSION, WENATCHEE, WASH.

- (b) Laboratory project.
- (d) Field investigations; basic and applied research.
- (e) Field studies in ponderosa pine and mixed-conifer forests and forest-ranges on the east slopes of the Cascade Range in Oregon and Washington: Erosion in forests and ranges: (1) Sediment production from Swauk sandstone-ponderosa pine; (2) sediment production from grazed pine-fir-larch ranges, Blue Mountains; (3) stimulation of seeded and natural grass cover by fertilization - Swauk sandstone soils; (4) relation of parent material and vegetative cover to organic matter, aggregation, pH, and bulk density of forest-range soils - eastern Washington; (5) effect of climate on development of soils from identical parent rock. Evapotranspiration: Includes studies with the overall objective of measuring factors which affect distribution and use of water in forests and related ranges: (1) Measurement of solar energy in a pine forest; (2) seasonal changes in soil moisture under a lodgepole pine forest; (3) measurements of moisture use by plants; (4) effect of removing brush and tree growth in three experimental watersheds on water yield (Entiat watershed study, in calibration stage -- no treatment yet applied); (5) water-holding capacity and drying rates for humus types characteristic of ponderosa pine-Douglas-fir forests - east side of the Cascade Range.
- (g) Radioisotopes have been used by other researchers for tracing movements of marine sands and sediments by fixing radioactive materials in a ceramic matrix on the surface of sand and sediment particles. A new technique was tried in which radioactive ferric⁵⁹ chloride in solution was placed directly on the soil surface in the field. The assumption was verified that reduced ferric⁵⁹ ions were primarily either bound or fixed as ferric oxide precipitates or humus coatings on soil particles and aggregates. Two weeks after application, very little isotope occurred in a water soluble form and even less on the soil base exchange capacity. Over 80 percent of the isotope applied was retained in the surface soil crust (1/8 to 1/4 inch). Six-tenths of 1 percent of this amount was water soluble, and 0.4 of 1 percent was removed from the exchange capacity. All of the isotope was retained in the surface 1 inch of soil. 92 percent in the surface 0.3

inch. These results make possible the tracing of soil particle erosion by following the movement of iron⁵⁹. Actual field erosion of soil particles was also investigated. This initial study tested two application patterns--lines and spots. There has been definite isotope movement on both ends and some slight downslope erosion in the middle of the line. There has also been limited isotope movement downslope from the spot.

- (h) "Effects of Parent Material and Vegetation on Properties Related to Soil Erosion in Central Washington," by David D. Wooldridge. Soil Sci. Soc. Proc. Vol. 28(3):430-432, May-June 1964.

(4758) WATERSHED LOGGING METHODS AND STREAMFLOW.

- (b) Laboratory project with some phases in cooperation with City of Portland, Bureau of Water Works and Oregon State University.
- (d) Field investigations; basic and applied research.
- (e) Research is conducted at three field locations in the Cascade Range of western Oregon: Bull Run watershed (domestic supply area for Portland), H. J. Andrews Experimental Forest, and South Umpqua Experimental Forest. Studies are confined to two forest types representing major segments of the remaining old-growth forests of the Pacific Northwest: (1) Douglas-fir, western hemlock, western redcedar, and (2) Douglas-fir, sugar pine. Investigations represent an initial effort to study precipitation runoff, erosion, and soil moisture in undisturbed stands, and to follow changes caused by several methods of logging. Included are studies in four categories: (1) Soil movement on logged land and an evaluation of effectiveness of grass seeding on roadbanks; (2) changes in water quality resulting from roadbuilding, two methods of cable logging, two degrees of forest removal -- 25 percent and 100 percent -- and slash burning; (3) changes in streamflow caused by clear cutting and partial cutting in groups of varying size on matched watersheds in old-growth Douglas-fir and sugar pine-fir. Pretreatment measurements are still being made to provide statistical basis for treatment evaluation; (4) soil moisture movement and disposition and the role of vegetation in evapotranspiration, including measure of seasonal changes in soil moisture under a Douglas-fir stand, vertical movement of water in Douglas-fir soils, rainfall interception by crowns of old-growth Douglas-fir soils, rainfall interception by crowns of old-growth Douglas-fir, and changes in plant succession following logging and slash burning.
- (g) Soil surface condition and bulk density were investigated after tractor and high-lead logging. The surface area of four clear-cut units was classified into four disturbance classes by means of point sampling. High-lead and tractor areas had about the same proportion in the slightly disturbed and deeply disturbed classes (approximately 23 percent and 9 percent respectively). The tractor-logged area had about three times more area within the compacted class than did the high-lead (27 percent vs. 9 percent), and a corresponding decrease in the amount in the undisturbed class (36 percent of the tractor area vs. 57 percent after high-lead logging). Surface soil bulk densities of samples from undisturbed and slightly disturbed areas were the same as prelogging values. Values for both the deeply disturbed and compacted classes were significantly higher, indicating a decrease in soil porosity. Compaction undoubtedly results in increased runoff and erosion. However, these undesirable effects are minimized if slopes are gentle and skid-trails correctly located. Streamflow from small drainages on the

western slopes of the Oregon Cascades is strongly influenced by a maritime climate characterized by excessively wet winters and dry summers. Although annual precipitation is high (94 inches in the study area), surface runoff is virtually unknown. Peak flows result largely from subsurface flow and under conditions in which both retention and detention storage are filled during extended periods of low intensity rainfall. Under these conditions, vegetation appears to exert a minimum influence on high streamflow. Lowest streamflow occurs from late August to mid-November and may follow a 60-100 day period with little or no rain. The dense vegetation of this portion of the Douglas-fir region appears to exert its major influence at this time. Removal of vegetation from only a portion of a 250-acre watershed has shown a 12- to 22-percent increase in minimum streamflow.

All soils are derived from volcanic rocks and exhibit unusually low bulk densities, generally well below 1.0 gm/cc. Soil textures range from medium to fine. Soils derived from reddish tuffs and breccias are finer textured than those found on greenish tuffs and breccias. The least permeable soil layers generally allow percolation rates of 4 inches per hour or greater. Most soils have large moisture storage capacities (up to 35 inches in the surface 100 inches of soil). This is largely due to the deep deposits of colluvium and well-decomposed rock which underly many of the soils.

- (h) "Storm Runoff Characteristics of Three Small Watersheds in Western Oregon", by Loyd O. Barnett, Jr. M. S. Thesis, Colo. State Univ., 84 pp. 1963.
"Net Precipitation Under a Douglas-Fir Forest," by Jack Rothacher. Forest Sc. 9(4): 423-429, Dec. 1963.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
Pacific Southwest Forest and Range Experiment Station.

(4996) WATERSHED MANAGEMENT RESEARCH IN CALIFORNIA'S
SNOW ZONE (SNOW MANAGEMENT RESEARCH).

- (b) Laboratory and the following cooperators: State of California, Dept. of Water Resources, Atomic Energy Commission, and Pacific Gas & Electric Company.
- (c) Dr. James L. Smith, Project Leader, Snow Management Research, Pacific Southwest Forest & Range Experiment Station, 1960 Addison Street, Berkeley 1, California.
- (d) Experimental; field investigations; basic and applied research.
- (e) The objective of this project is to determine methodology for increasing water yield and changing of timing of water delivery by vegetation manipulation, by evaporation suppressants, etc. Its area of interest is confined to the snowpack zone of the Sierra Nevada of California. Present studies emphasize development of methods for management of high elevation snowpacks for yield and control of water; the effects of timber cutting upon soil moisture losses and snow accumulation and melt; and the evapotranspiration from various sites -- species combinations.
Project scientists are located in Berkeley with field personnel and studies located at the Central Sierra Snow Laboratory, Soda Springs, California, and studies only located at Teakettle Experimental Forest in the headwaters of the north fork of the Kings River above Fresno, California. Both sites lie at 7000-8000 feet elevation. At the Teakettle Experimental Forest four small watersheds (0.27-0.86 square miles in area) are under study prior to installation of log roads and a timber harvest to determine their effects upon water yield and sediment. At the Central Sierra Snow Laboratory five small watersheds are gaged for the study

of logging effects upon water yield. In the headwaters of the Feather River a practical sized logging is being tested for snow accumulation and melt effects. Gamma and neutron probes are being tested for measuring hydrologic characteristics of snowpacks. Evaporation suppressants are being tested for reduction of such losses from snowpacks.

- (g) Rapid measurement of hydrologic characteristics of snowpack which may permit more accurate appraisal and prediction of delivery of snowmelt water has been possible using gamma and neutron probes. Commercially available probes with gamma and neutron sources (Nuclear-Chicago, P-20 and P-19 probes) were tested for the ability to measure snow density, ice lenses, and the thermal quality (free water) of the individual layers in the snowpack. Usable regressions of snow density (D) at each depth, measured gravimetrically and with neutron counts (Cn) and gamma counts (Cg) in CPM in the snowpack were obtained. Much greater sensitivity of measurement was obtained by lowering a cesium source in one tube of a twin-tube probe and a detector in the other tube. This transmission method resulted in measurements to within 2 percent accuracy where a snowpack was profiled in 3-inch increments. Ice lenses in the snow were readily detectable by shifts in the neutron probe counts; neutron counts would increase markedly at the occurrence of ice; gamma counts were only slightly affected. In a study of changes in the thermal quality of snowpack throughout the day and from day to day, neutron counts were directly related to the percentage of ice in the snow, as contrasted with free water. Winter surface evaporation from snowpack at high elevation sites were reduced by the addition of the suppressant hexadecanol. Snow density at maximum pack (near April 1) was found to be constant for an aspect regardless of the cover density or even lack of cover. While mean snow depths for various cover conditions ranged from 67.1 to 83.5 inches, snow density ranged from only 31.6 to 34.9 percent. Standard deviations for depth ranged from 10.28 to 16.30; for density the range was from 1.93 percent to 3.17 percent. Snow water content accumulation (in area inches) by cover conditions amounted to: clear cut 27.5, scattered young timber 26.7, alder-willow thickets 27.6, natural openings in a forest 24.1, 20 percent forest cover 21.6, 40 percent forest cover 20.2, 60 percent forest cover 20.2. A stratified randomized sampling of the area using 210 sample points resulted in a mean standard deviation of 14.76 from a mean snow depth for all conditions of 72.7 inches. At the same time a line-transect sample using 428 points resulted in a mean snow depth for all conditions of 73.8 inches with a standard deviation of 17.3.
- (h) "Summer Evapotranspiration Trends as Related to Time After Logging of Forests in Sierra Nevada," by Robert R. Ziemer, Jour. Geophysical Research, vol. 69 No. 4, pp. 615-620, Feb. 15, 1964.

(4997) WATER SOURCE HYDROLOGY.

- (b) Laboratory project. Cooperators are: State of California, Department of Water Resources; University of California; State of Hawaii, Division of Forestry.
- (c) Mr. Henry W. Anderson, Project Leader, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley 1, California.
- (d) Experimental and theoretical; basic and applied research.
- (e) The objective is through analytical modeling to advance the state of knowledge of watershed hydrology and sedimentation, and particularly, knowledge of the relationship of watershed management and other hydrologic processes at the water sources to water yield, floods, sedimentation, and water quality delivered

- (g) from wildland watersheds. Laboratory analyses of the soil samples taken in the study of erodibility of Hawaii wildland soils has been completed and some relationships of soil characteristics to site characteristics determined. Seventy-five sampling sites were used in obtaining the soil samples, selected along 26 transects of the Waianae and Koolau Mountain ranges of Oahu. Soils were sampled under trees, shrubs, or grass cover under widely different precipitation, aspect, and elevational and geologic conditions. Parent rock was of three main types: basaltic flows, pyroclastic deposits, or detrital materials. A variety of multiple regression, principal components (including varimax rotation), canonical, and factor analyses have been run on the data. Soil characteristics were the dependent variables and geology, zone, vegetation type or species, rainfall and elevation were the independent variables. Soil characteristics included the mean weight diameter of water stable aggregates, various fractional sizes of aggregates, and suspension percent. These soil characteristics were predictable from the site variables, with the explained variance ranging from 52 to 76%. Precipitation, elevation, geology, and vegetation were significant, but the interaction of geology and vegetation was not significant at the 5% level. Regressions using vegetation species as a variable were more significant than those using vegetation types. Air-drying soil samples, before determining the aggregate sizes, reduced the predictability of the soil characteristics as compared with keeping the samples moist before laboratory analysis. Of the multivariate techniques used, principal components with varimax rotation gave good predictability and easily interpreted factors. Estimation of soil moisture and snow storage from climatic variables for input to watershed runoff analyses has been developed using a simulation program. A 7094 program computes daily values of potential evaporation, soil moisture deficit or excess, available moisture, and storage capacity, together with accumulation and melt of the snowpack. Input data are from the U. S. Weather Bureau 1009 daily weather cards; other controlled information entered are relative day length for a given latitude and date, soil moisture storage capacity, degree-day melt factor, and degree-day base temperature. Different levels of total soil moisture capacity may be assumed and different temperature adjustments made to the daily temperature data. Tests of the applicability of various multivariate analysis methods to the problems in hydrology have been explored using a known physical model (a hollow cylinder), employing both rational and somewhat irrational measurements on the physical system. Multiple regression, stepwise multiple regression, principal components analysis, varimax rotation and regression, oblimax rotation, and key cluster analyses have been tested. Principal components analysis with varimax rotation and key cluster analyses gave similar results and seemingly rational clues to the physical system. Analyses of soil moisture data collected in Hawaii during 1960 and 1961 in a cooperative program with the Corps of Engineers have been analyzed to determine the effectiveness of rainfall in charging the soil. Data were selected when available storage in the soil exceeded precipitation, and the relationship of soil moisture accumulation to available storage, precipitation their squares and interactions, determined by principal components analysis, separately by species and site for two amounts of daily rainfall, 0.25 and 0.50 inches, the effectiveness in percent of the rainfall for six sites is summarized below:

Species	Soil Moisture Gain,	
	percent of precipitation	
	Precip.=0.25	Precip.=0.50
Bamboo	8	59
Eucalyptus spp.	31	49
Grass	33	45
Uluhi-Ohia	38	47
Pineapple	41	70
Eucalyptus robusta	50	41

Note that for precipitation of 0.25 inches, which was about the mean daily precipitation, very little of the rainfall in the bamboo stand reached and charged the soil -- only 8 percent; however, with more precipitation, 0.50 inches, soils under bamboo were second most effectively charged with moisture, only exceeded by soils under pineapple. Soils under grass did not differ markedly from soils under the tree species. Because surface runoff was probably negligible from storms of these sizes, one might infer that differences between precipitation and soil moisture gain is a measure of interception (or more precisely, the combined interception and evapotranspiration). Variation in soil moisture accumulation explained by rainfall ranged from 60 to 85%, with the highest explained variance being under the pineapple, and the lowest under the two eucalyptus species. Rainfall-runoff relations for two 30-acre wildland watersheds (Kaukonahua Watersheds on Oahu) were determined from the records collected by the territorial Forester in the water years, 1952 to 1955. Relations were compared for the natural conditions of tree vs. fern-covered watersheds and relations after the fern watershed was burned and partially planted trees in 1953. After adjustment for differences in antecedent precipitation and storm characteristics, the total storm runoff (Q_s) and the storm precipitation (P_s) were found to remain highly consistent between periods, but vary widely between the tree vs. the fern watersheds. Explained variance ranged from 55 to 90% when principal component analysis was used. Equations relating storm runoff and storm precipitation, both in inches, are given below, together with computed runoff from the average size storm of 2.0 inches:

Condition	Equation	Qs (P=2.0)	
TREE (1952, 1953)	$Q_s = 0.051 P_s \exp. 1.24$.120	
TREE (1954, 1955)	$Q_s = 0.042 P_s \exp. 1.28$.102	
FERN (1952, 1953)	$Q_s = 0.065 P_s \exp. 1.53$.188	
FERN (1954, 1955)	$Q_s = 0.068 P_s \exp. 1.52$.195	

Note that storm runoff from the fern watershed was approximately two times that from the tree watershed in both periods.

- (h) "Variation in Dispersion Ratio, Surface Aggregation Ratio, and Texture of Some California Surface Soils as Related to Soil-Forming Factors", by J. R. Wallis and D. W. Willen, Internat. Assoc. Sci. Hydrol. Bull. VIII, No. 4, pp. 48-58, 1963.
 "Some California Hydrologic Problems and Solutions", by Henry W. Anderson, Hydrology Study Tour, XIII General Assembly I.U.G.G., Bul. Internat. Assoc. Sci. Hydrol. IX Année, No. 2, pp. 5-18, 1964.
 "Effect of Stream-Ordering Technique on Horton's Laws of Drainage Composition", by Kenneth L. Bowden and James R. Wallis, Geol. Soc. Amer. Bul. 75(8): 767-774, 1964.

- (4998) WATER YIELD IMPROVEMENT, AND FLOOD AND SEDIMENT REDUCTION IN THE LOWER CONIFER ZONE

OF CALIFORNIA.

- (b) Laboratory project. Cooperators are: California Department of Water Resources, California Division of Forestry, East Bay Municipal Utilities District, California Department of Fish and Game.
- (c) Mr. Robert P. Crouse, Project Leader, Lower Conifer Zone, Pacific Southwest Forest & Range Experiment Station, 1960 Addison Street, Berkeley, California.
- (d) Experimental; field investigations; basic and applied research.
- (e) This project conducts basic studies of forest hydrology which will suggest methods of land management for improving water yield, preventing floods and controlling sediment in the commercial timber zones of California below the snowpack. A study of soil moisture depletion in the Sierra zone of the Lower Conifer Zone concerns the magnitude of soil moisture storage and depletion under different stand and timber cutting intensities. Because soil creep and landslides are prevalent in the zone, a study of gravitational mass movement will form an effort to develop the means of estimating the consequences of mass movement in terms of sedimentation. The ultimate objective is to develop the means of predicting the role of land management practices, such as logging and road building in initiating or accelerating mass movement.
- (g) Soil moisture data has been collected at 2-week intervals from 84 neutron moisture meter access tubes installed to a depth of 20 feet in a wide range of logging intensities. Water table observation wells have been drilled to a depth of 50 feet for the purpose of evaluating capillary recharge to the unsaturated soil rooting depth. The standard Radium-beryllium sources in the neutron meters have been replaced with Americium-beryllium sources. The second experimental site of the soil creep study has been located in a 35-mile zone transecting the Coast Ranges in the vicinity of Fort Bragg and Covelo. The watershed calibration period at Caspar Creek is continuing with measurements of streamflow, sediment discharge, and precipitation.
- (4999) FLOOD AND SEDIMENT REDUCTION FROM STEEP UNSTABLE BRUHLANDS OF THE SOUTHWEST.
 - (b) Laboratory project. Cooperators: California Division of Forestry, Los Angeles County Flood Control District, Los Angeles County Fire Department, University of California, Berkeley, Los Angeles, and Riverside, Angeles National Forest.
 - (c) Mr. Raymond M. Rice, Project Leader, Pacific Southwest Forest and Range Experiment Station, 110 North Wabash Avenue, Glendora, Calif.
 - (d) Experimental; field investigations; basic and applied research.
 - (e) Purposes are (1) to determine how watersheds function: what happens to the precipitation, and how water and soil movement are influenced by conditions of vegetation, soil, geology, and topography; and (2) to develop methods of watershed management, including treatment of areas denuded by fire, to insure maximum yield of usable water and satisfactory flood, runoff and soil erosion control. Principal work center is the 17,000-acre San Dimas Experimental Forest situated in the San Gabriel Mountains. A fire started by lightning in July 1960 consumed the vegetation, mostly brush, on 90 percent of the area and destroyed or damaged many of the research installations. Immediately after the fire a major emergency research program was started to test the effectiveness of various measures used to reduce flood runoff and erosion on the denuded watersheds. These rehabilitation measures include seeding grasses and mustard singly and in combination with physical treatments such as wattling, channel barriers and contour terraces. The tests are being made on 38 watersheds of 2 to 90 acres each, equipped to measure rainfall intensity, peak discharge and suspended sediment. Twenty-five have basins to measure bedload. Studies of the erosion processes and tests of applied management methods to decrease the erosion potential are being continued.
- (g) The lack of rapid infiltration over a burned watershed contributes to excessive surface runoff. Reducing debris movement from burned watersheds then appear to be partly a problem of getting water into the soil mantle. Surface soils following a fire are usually "non-wettable" as a result of particle coatings with a chaparral leachate. In a recent burn, we tested a wetting agent treatment on six small plots. The objective of the treatment was to establish the suitability of a surfactant for reducing debris movement. During the dry winter of 1962-1963, the plots treated with the wetting agent produced 95 percent less debris and 32 percent less surface runoff than the treated plots. There was additional evidence that the treatment benefited grass establishment. The treated plots had four times the vegetative cover of the untreated controls. This year field plots have been installed to evaluate the effectiveness of a surfactant when applied by two methods which would be practical for wide spread aerial applications. The disposition of the surfactant in the soil has not been evaluated. A question of prime importance is the longevity of such a chemical treatment. Laboratory studies are underway to estimate the ability of a wetting agent to persist in soil through numerous wettings and dryings.
- (h) "A Study of Trapezoidal Flume Models at San Dimas", by Richard R. Brock and Jay S. Krammes, U. S. Forest Service Research Note PSW-50, 1964. "Soil Wettability as a Factor in Erodibility", by J. F. Osborn, R. E. Felishek, J. S. Krammes, and J. Letey, Soil Sci. Soc. of Amer. 28(2): 294-295, March-April 1964. "Wetting Agents Can Reduce Soil Erosion", by J. F. Osborn, R. E. Felishek, J. S. Krammes, and J. Letey, Crops and Soils, Aug.-Sept. 1964. "First Aid" for Burned Watersheds", by J. S. Krammes and L. W. Hill, U. S. Forest Service Research Note PSW-29, 1963. "Effects of Fire on the San Dimas Experimental Forest", by J. S. Krammes and R. M. Rice, Arizona's 7th Ann. Watershed Symposium Proc., 1963.
- (5000) WATER YIELD IMPROVEMENT FROM THE BRUHLANDS OF THE SOUTHWEST.
 - (b) Laboratory project. Cooperators: California Division of Forestry, Los Angeles County Flood Control District, and University of California at Berkeley, Riverside, and Los Angeles.
 - (c) Mr. Leonard F. DeBano, Project Leader, Pacific Southwest Forest and Range Experiment Station, 110 North Wabash Avenue, Glendora, Calif.
 - (d) Experimental; field investigations; basic and applied research.
 - (e) The work center is the 17,000-acre San Dimas Experimental Forest in the San Gabriel Mountains of Southern California. Field investigations include studies concerned with the hydrologic factors of chaparral watersheds, riparian zone hydrology, and evaluation of water yield improvements. Laboratory studies on the movement (saturated and unsaturated), loss and storage of water in brushland soils supplement field studies on chaparral and riparian zone hydrology. Purpose of the work is (1) to establish fundamental plant, soil, water relationships as they influence water losses and water

- yields; and (2) to develop and test cultural practices aimed at improving water yield.
- (g) Basic laboratory studies are being conducted on unsaturated moisture movement in soils which are difficult to wet. The "non-wettable" condition exists as a soil layer parallel to and below the soil surface. The upper part of this non-wettable layer which is of variable thickness, is located about 1-3 inches below the soil surface. The presence of the non-wettable layer appears associated with burned and unburned watersheds which either have or are supporting a dense cover of chaparral brush. Laboratory experiments carried out in the laboratory indicate that the non-wettable soil property can be altered by heat treatments. Heating in a muffle furnace at 800° F for 18 minutes destroys the non-wettable property, whereas heating at the same temperature for only 7-8 minutes intensifies it. Preliminary results from horizontal infiltration experiments carried out in the laboratory indicate that the non-wettable soils have different moisture transmitting properties than similar textured wettable soils. The time required for water to move 20 cm in soil columns packed with wettable soil was 78 minutes while in the non-wettable soil it was 1,861 minutes. The soil moisture distribution between the water source and the wetting front was also different for the wettable and non-wettable soils. In the wettable soil the soil moisture content decreased about 10 percent between the water source and the wetting front, whereas for the non-wettable soil it decreased about 25 percent. Both wettable and non-wettable soils had the same moisture percentage at the water source and the difference in moisture content increased uniformly as the wetting front was approached. Evaporation experiments on columns packed with wettable and non-wettable soils indicated that the presence of a non-wettable substance also effects evaporation phenomena. The amount of water lost from wettable soils was about 85 percent greater than that lost from non-wettable soils during a 90-day evaporation period. Infiltration and evaporation studies on soil columns having a non-wettable soil layer of varying thickness are now being planned. These experiments will more nearly simulate the arrangement of the soil layers under field conditions.
- (h) "Effect of 2,4-D and 2,4,5-T on Water Quality after a Spraying Treatment" by Jay S. Krammes and David B. Willets, U. S. Forest Service Research Note PSW-52, 1964.
- "Chaparral Succession in a San Gabriel Mountain Area of California", by J. H. Patric and T. L. Hanes, Ecology 45(2): 353-360, 1964.

(5001) WATER YIELDS IN HAWAII.

- (b) Laboratory project. Cooperators: State of Hawaii, Department of Land and Natural Resources, Div. of Forestry.
- (c) Mr. Robert E. Nelson, Chief, Hawaii Research Center, Pacific Southwest Forest and Range Experiment Station, 400 South Beretania St., Honolulu, Hawaii.
- (d) Experimental; field investigations; basic and applied research.
- (e) The objective is to develop a hydrological and meteorological base in Hawaii's wildland watersheds that will suggest methods of land management for maintaining or improving water yield and water quality and minimizing soil erosion and sedimentation; to obtain adequate understanding of the processes of receiving and discharging water and being able to predict the effects of a wide span of forest land management practices upon water yield and water control; such studies are to suggest ways to manage watersheds that will (1) assure

the continued protection of watersheds; (2) improve the distribution of the water yield by modifying the balance between the ground-water recharge and surface waterflow; (3) increase water yields by decreasing evapotranspiration losses; and (4) minimize flood runoff and sedimentation. Major work center is in Honolulu. The principal studies under way are the determination of soil erodibility indices for forest soils in Hawaii, the measurement of evapotranspiration from several selected wildland vegetation types, and a study of rainfall-runoff relations on two small forest watersheds.

- (g) Erodibility indices found useful elsewhere have been determined from soils collected along transects across the major mountain ranges on Oahu. Parent material, vegetation type, precipitation, and elevation significantly affect erodibility. Summer evapotranspiration losses during 1963 in the Waianae Range of Oahu varied from about 11 inches for grass, 17 inches for brush and up to 20 inches for paperbark Eucalyptus. Losses for the summer of 1964 were appreciably less because of limited rainfall, both during the winter soil moisture recharge period and during the summer. Detailed analyses of rates of loss at various depths are under way. Analyses of the rainfall-runoff relations on two small watersheds indicate that an intentional burning of the uluhi fern on one had little, if any, effect. Likewise, no effect on runoff of replanting the burn to forest tree species was detectable the first 2 years after replanting. Plans call for the publication of the results of these studies. New studies of the effect of forest plantations on the value of forest lands as producers of water will be initiated.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Rocky Mountain Forest and Range Experiment Station.

Inquiries concerning the following projects should be addressed to Mr. Raymond Price, Director, Rocky Mountain Forest and Range Experiment Station, Room 221 Forestry Building, Fort Collins, Colorado 80521.

(377) WATERSHED MANAGEMENT RESEARCH, FRASER HYDROLOGIC LABORATORY.

- (b) Laboratory project.
- (d) Field investigations; applied research.
- (e) To determine influence of lodgepole pine and spruce-fir forests and of the management of these forests for wood products on factors associated with the yield of water, largely from stored snow. The purpose is to solve problems in the management of forested watersheds of the high altitude zone of the Rocky Mountains for maximum yields of usable water.
- (g) Data from 82 snow sampling locations were used to investigate snow cover depletion and ablation on Fool Creek in relation to selected physiographic characteristics of the watershed and streamflow. This watershed possesses relatively uniform topography with respect to exposure, solar radiation, and other factors affecting deposition and melt. A comparison of the snow cover depletion, ablation, and generated runoff relationships for the period April 1-July 31, 1952, indicates that ablation began several weeks prior to both the spring rise of Fool Creek and the appearance of bare ground. In addition, the rate of ablation was much faster than the rate of depletion. Approximately 60 percent of the area was snow covered on the peak day (June 10). However, the pack contained only about 30 percent of the seasonal water equivalent. A comparison between the cumulative ablation and cumulative generated runoff relationships also indicate that there was a greater volumetric decrease

of the pack than was indicated by generated runoff. The displacement of the ablation curve relative to the generated runoff curve is due to losses. Almost all of the losses to the water yield from snowmelt occurred prior to the time of peak streamflow. The steepness of the depletion curve also reflects the rather homogeneous physiographic characteristics of this watershed. The snow cover remained intact for a relatively long time and depletion took place rapidly. Final analysis of the observations made in the snow physics study during February and March of 1963 have been found to support the hypothesis (Bergen 1963) of extensive buoyant convection within the snow cover at these periods with warm current velocities in the range of turbulent flow (1 to 2 cm. sec.⁻¹ for the snow cover examined).

These convective currents appear to be of a continuous character resembling the buoyant plumes studied in homogeneous media and representing a continuous flow of soil heat to the upper layers of the snow cover. Such currents tend to sustain higher average surface temperatures for the snow cover and thus in general higher ablation rates in a given environment than would otherwise be the case. A more significant effect is the increase in grain size at the upper layers due in part to the moisture transport by these currents. Accretion of this moisture by the surface granules may be an important factor in the rapid decrease of albedo observed through the months of deep snow cover amounting to a two-fold increase in the absorption of solar energy and a consequent acceleration of daytime ablation rates.

- (h) "Vapor Transport as Estimated from Heat Flow in a Rocky Mountain Snowpack," James D. Bergen, Internatl. Assoc. Sci. Hydrol. Pub. 61, pp. 62-74, illus.

(657) WATERSHED MANAGEMENT RESEARCH, TEMPE, ARIZONA.

- (b) Laboratory project.
(d) Experimental; basic and applied research.
(e) To study the disposition of rainfall as influenced by watershed vegetation; to determine the influence of various types of forest and grassland vegetation as well as vegetation modified by cultural treatment such as grazing and timber harvest, on streamflow, water use, water loss, and erosion and sediment yield; and to determine for phreatophytic vegetation (water-loving plants) the amount of water used, methods for reducing water use by phreatophytes or for replacing them with more useful plants. At Sierra Ancha Experimental Watersheds in central Arizona, rainfall, runoff, and erosion are measured on three watersheds in the pine-fir vegetation type at high elevation, on two watersheds in the ponderosa-chaparral type, and from four watersheds in the grassland-chaparral type at intermediate elevations, and on nine small watersheds in the semidesert-chaparral type at low elevations. Water use by different types of plants in various soils is studied on eleven large lysimeters. Three watersheds have been established on the ponderosa pine type, three in the mixed-conifer type, and two watersheds in the high (9,300-foot elevation) grassland type. Current plans are to treat one ponderosa pine watershed in 1965, testing current Forest Service methods of harvesting mature timber, but adjusting cutting methods to lead to eventual even-aged management. Soils from grass, aspen, and mixed-conifer plots are being laboratory tested for hydrologic characteristics. Soil moisture is followed with a neutron probe. Gaging stations for four watersheds in the pure chaparral type are also available to evaluate watershed-game interrelations. One cluster of two watersheds and another cluster of three watersheds are available for testing the effect of mani-

pulating chaparral cover. Supplemental studies are determining the proper use of chemicals, fire, and mechanical treatment for manipulating shrub in the type. Ecology of *Tamarix pentandra* and other phreatophytes is under investigation. Germination, seedling survival, sprouting ability, and rate of spread studies were continued. Clearing 80 acres of moist-site forest vegetation, dominantly white and Douglas-fir, and replacement with grass in the 248-acre North Fork of Workman Creek Watershed, caused an average of about a 55% increase in water yield. Water yields for the treatment period are also fairly well distributed along the posttreatment regression as follows:

	Actual Streamflow (Inches)	Expected streamflow (Inches)	Percent increase
1958-59	1.4	0.9	56
1959-60	6.4	4.4	45
1960-61	1.6	1	60
1961-62	5	3.1	61
1962-63	3	1.8	67

Results of timber harvest on South Fork in which 45% of the basal area of trees were removed by individual tree selection did not change water yields significantly. The gravimetric determination of moisture in airstreams is presently being investigated. The purpose of the study is to develop methods for determining water vapor in airstreams by means of adsorbents and/or absorbents, and refrigerants. The amount of water collected is then determined gravimetrically. This method is of interest for the purpose of providing a measure of total water loss from chaparral shrubs over a period of several hours.

A group of desiccants was tested in a system in which air was saturated with water at 30 °C, and was then passed at a constant rate through three U-tubes of a given desiccant. A total volume of 10 cubic feet of air was passed through the system for each test.

The results of these tests indicated that silica gel was the most desirable desiccant for the type of system used. It combined more desirable characteristics than the other desiccants tested, and adsorbed all of the moisture in the first U-tube. Artificial reseeding with Lehmann lovegrass and transplanting of native curlymesquite grass clumps on Base Rock lysimeters 3 and 2, respectively, was completed during summer of 1961 and 1962. Artificial watering was considered necessary during the late spring-early summer dry period, ending on Sept. 20, 1962. The original grass and halfshrub cover was left undisturbed on (control) lysimeter number 1.

Following replanting in 1962 and through the summer of 1963, surface flows from lysimeters 2 and 3 exceeded that from lysimeter 1. During late winter of 1962-63 percolation flows from the two were greater than from lysimeter 1, with the same condition generally carrying through the summer of 1963. The winter of 1963-64 had less precipitation than in 1962-63 and there has been no appreciable differences between the water yields of the three lysimeters. Following a wildfire in June 1958, shrub sprouts were "controlled" on a 76-acre watershed by repeated aerial spraying. Shrubs were sprayed each May for four successive springs. Treatment consisted of 2 pounds active of 2,4,5-T ester, although other chemicals (TBA, PBA, 2,4-D) were also tried.

Repeated chemical treatment held shrub cover on Watershed "C" to about 5%, which on an adjacent untreated watershed, cover rose to 34%. However, something less than 40% of the dominant species, shrub live oak, was

actually killed. Higher kills were noted on other less abundant chaparral shrubs. Dense growth of chaparral morningglory (*Ipomea coccinea*) and other forbs and grasses, plus the mass of dead brush sprouts, formed an "umbrella" over new shrub sprouts and appeared to make further aerial spraying unpromising. Therefore, in August 1964 all surviving shrubs were hand treated with 25% fenuron at the rate of 16 pounds active ingredient per acre. Amount of chemical per shrub was based on its crown area; e.g., a 4-foot diameter shrub was treated with about 11 grams of fenuron. The chemical was sprinkled uniformly through the crown. All plants 0 to 4 feet in diameter received the same treatment. It is expected that this treatment method will cause minimum damage to the excellent stand of seeded and native grasses and, therefore, will have little effect on soil stability on these steep, highly erodible slopes.

- (h) "Notes on the Introduction of Deciduous Tamarisk," Jerome S. Horton, Research Note RM-16, 7 pp.
- "Vegetation Changes Following the Mingus Mountain Burn," Charles P. Pase and Floyd W. Pond, Research Note RM-18, 8 pp. illus.
- "A guide for Surveying Phreatophyte Vegetation," J. S. Horton, T. W. Robinson, and H. R. McDonald, U.S.D.A. Handbook 266, 37 pp., illus.
- "Simultaneous Studies of Transpiration Rate and Sap Velocity in Trees," J. P. Decker and C. M. Skau, Plant Physiology 39: 213-215, illus.
- "Soil Water Storage Under Natural and Cleared Stands of Alligator and Utah Juniper in Northern Arizona," C. M. Skau, Research Note RM-24, 4 pp. illus.
- "Compact Field Kit for Aerial Photographic Interpretation," C. J. Campbell, Jour. Forestry 62: 266-267, illus.
- "Comparison of Eighteen Phreatophyte Communities on the Rio Grande in New Mexico," C. J. Campbell and W. A. Dick-Peddie, Ecology 45: 492-502, illus.
- "Potential Insolation as a Topoclimatic Characteristic of Drainage Basins," Richard Lee, Internatl. Assoc. Sci. Hydrol. Bul. 9 (1): 27-41.

(1969) WATERSHED MANAGEMENT RESEARCH, ALBUQUERQUE, NEW MEXICO.

- (b) Laboratory project. Some work in cooperation with Bureau of Land Management and Geological Survey.
- (d) Applied research.
- (e) Evaluation of range-watershed conditions on small watersheds in the San Luis drainage of the Rio Puerco. Three contiguous watersheds, ranging from 338 to 555 acres located about 8 miles north of the San Luis community and west of the Rio Puerco main channel provide the study area. Water and sediment inflow are measured in small reservoirs formed by earthen dams. Precipitation rates and amounts of vegetation changes are periodically measured over the watersheds. Ten years of data have been collected under cattle grazing during a 5 1/2-6 month overwinter period (November 1 to April 30). Evaluation of soil ripping on surface runoff, erosion, and vegetation. Surface runoff plots (64), 10' x 31', are installed on a north and south aspect and upper and lower slopes representing different soil conditions in the Rio Jemez drainage. Precipitation, runoff, and sediment are measured.
- To obtain inventory information on the hydrologic variables of the pinyon-juniper type, six small watersheds with ephemeral streams are being gaged by means of a prefabricated, fiberglassed version of the Beaver Creek flume.
- (g) On 12 watersheds in New Mexico, size of watershed, percent bare area, and parent soil material had an important effect on the portion of precipitation measured as runoff. Between 0.8

and 9.3 percent of precipitation showed as runoff in areas of about 12" of annual precipitation. Construction details and costs for a sample plot to measure runoff and erosion have been published.

On a 400-acre test area sprayed with 2,4,DP just as new growth started, kill ranged from 95 to 100%. The herbicide, which must cover the plant completely, is equally effective as a mist or large-drop spray. Soil ripping reduced surface runoff 96% and erosion 85% the first year; reductions were 85% and 31% respectively, after 3 years. Surface pits were ineffective after 3 years. These mechanical treatments may have initiated or speeded up undesirable soil piping.

Utilization patterns on small watersheds grazed by yearling cattle were about the same before and after fencing. Yearling heifers gave more uniform utilization on rough terrain; mixed classes gave most uniform use when grazed on open range.

- (h) "Controlling Cane Cactus with 2,4,DP," George Garcia and Wayne C. Hickey, Jr., Research Note RM-15, 2 pp. illus.
- "An Evaluation of Soil Ripping and Soil Pitting on Runoff and Erosion in the Semiarid Southwest," Wayne C. Hickey, Jr., and E. J. Dortignac, Internatl. Assoc. Sci. Hydrol., Pub. 65, pp. 22-33 illus.
- "Range Utilization Patterns as Affected by Fencing and Classes of Livestock," Wayne C. Hickey, Jr., and George Garcia, Research Note RM-21, 8 pp. illus.
- "A Device for Cutting Uniform Inch-Height Segments of Plants and Plant Parts," Wayne C. Hickey, Jr., Jour. Range Mangt. 17: 154-155, illus.

(2658) WATERSHED MANAGEMENT RESEARCH, RAPID CITY, SOUTH DAKOTA.

- (b) Laboratory project.
- (d) Experimental; basic and applied research.
- (e) (1) To evaluate water yield and sediment production in relation to standard forest management practices in ponderosa pine. (2) To determine surface runoff and rates of recovery from soil compaction on Kentucky bluegrass range in the Black Hills. (3) To determine soil moisture relations of ponderosa pine thinned to different reserve densities and by stand types.
- (g) First year record from the first of the three gaged Sturgis watersheds shows interesting characteristics. The three watersheds are located on one of a number of rather extensive cenozoic igneous intrusions of the northern Hills. Topography is rough, slopes are steep, soils are relatively shallow and apparently highly permeable. The entire area is timber covered (ponderosa pine) and has been little disturbed for many years. Watershed 1 (217 acres) yielded 11 inches, 202 acre-feet, of water from December 1, 1962, through Sept. 30, 1963. Total precipitation was 28.83 inches during the same period. Flow response to heavy precipitation is apparently due more to rapid drainout than to surface runoff. The individual storm hydrograph for the heavy June 15 storm peaked nearly 3.5 hours after rain stopped. The absolute peak reached 63.7 c.s.m. Calculated concentration time for this 217-acre watershed is 13 minutes.

(3569) WATERSHED MANAGEMENT RESEARCH, LARAMIE, WYOMING.

- (b) Laboratory project.
- (d) Field investigation; applied research.
- (e) (1) To determine the effects of big sagebrush on total runoff from snowmelt, snow accumulation and storage pattern. Three high elevation sagebrush watersheds, 60 to 106 acres, in western Wyoming provide the study area. V-notch weirs gage the runoff, and suspended sediment samples

are taken periodically. Snowpack is sampled along permanent transects and at random points. Precipitation is sampled by a network of recording and non-recording gages. (2) To determine the soil moisture withdrawal pattern under natural stands of big sagebrush, and the effect of sagebrush eradication on moisture withdrawal. Four 0.1 acre plots on an east and a west exposure have been established within high elevation sagebrush type in western Wyoming. Sagebrush on two of the plots on each exposure has been eradicated by spraying. Soil moisture samples are taken periodically to trace moisture withdrawal under each condition. (3) To evaluate the comparative efficiencies in terms of water stored in accumulated snow, of tandem 4-foot slatted snow fences erected at different spacing intervals on open windswept slopes in southeast Wyoming. (4) To evaluate the effects of inducing snow accumulation on a watershed through use of artificial barriers. Three experimental grassland-type drainages, 88 to 144 acres, have been selected for the study area in southeastern Wyoming where snow transport by wind commonly occurs. V-notch weirs are installed to measure water yield. Snowpack is sampled in areas of natural accumulation along permanent transects. Summer precipitation is sampled by a network of recording and non-recording gages. (5) To determine the basic hydrology of mountain bogs in Wyoming. The prevalence of small bogs along many perennial streams in the mountains of Wyoming has stimulated the posing of various questions concerning the hydrologic significance of these areas in relation to management techniques for water yield improvement. To provide information basic to advanced studies oriented toward this problem, hydrologic characteristics of a 3-acre bog were studied intensively during the summer of 1963 and will be continued for another field season. Observations of vegetation and physical conditions on the bog indicate possible relationships between various species and environmental conditions such as peat depth and surface-water depth.

- (g) A significant relationship has been established between potential evapotranspiration calculated by Penman's equation and daytime evaporation pan measurements. Late summer measurements subsequent to the disappearance of a free water surface on the bog indicated that the water table had no diurnal oscillations but instead decreased in a stairstep fashion. Piezometer and well data suggest that the interchange of ground water across bog perimeters is a significant hydrologic property requiring further investigation. Preliminary drift-gage data indicate that the delivery of snow to a snow fence in a draw may have an efficiency of about 170 percent as compared to upland areas. Topographic features of a sample of draws were analyzed to arrive at a means of classifying channels into two classes: those that accumulate snow naturally and those that do not. Results suggest that the factors of cross sectional area (i.e., width, depth and width/depth ratio) may offer a means of predicting natural snow accumulation, and thus augment the basic information requisite to prescribing snow fence treatment on a watershed basis.

- (h) "The Root System of *Artemisia Tridactata* on a High-Elevation Site in Wyoming," R. D. Tabler, Ecology 45: 633-636, illus.

(3895) WATERSHED MANAGEMENT RESEARCH, ALPINE HYDROLOGIC LABORATORY.

- (b) Laboratory project.
- (d) Field investigations; basic research.
- (e) To determine methods for increasing the amount of snow storage in alpine snowfields, and to develop control of evaporation and melting to insure maximum effective contribution to summer streamflow. To reduce snow

avalanche danger by improved forecasting of hazard, and methods of stabilizing snowpacks on mountain slopes.

- (g) Wind seems the outstanding weather factor affecting the formation of direct slab avalanches at Berthoud Pass, Colo. All of the 27 slides (released) in this category were preceded by at least one period when the 6-hour average windspeed was ≥ 18 m.p.h. in the 48 hours prior to release. None were released when the greatest 6-hour average windspeed in the 48 hours prior to release was < 18 m.p.h. Precipitation amounts accompanying the wind were light. Only 25 percent of the slides occurred when the total precipitation preceding release was > 0.50 water equivalent.
- (h) "Snow Avalanche Occurrence and Control Along Colorado Mountain Highways," Hans Frutiger, Research Paper RM-7, 85 pp., illus.

(3896) WATERSHED MANAGEMENT RESEARCH, FORT COLLINS, COLORADO.

- (b) Laboratory project.
 - (d) Field investigations; applied research.
 - (e) Field plot to observe the adaptability and growth characteristics of twenty-three tree shrub and twenty-six grass and forb species for further testing on critical erosion sites. Research to find the influences of mechanical watershed rehabilitation measures on the microclimate and other site factors in the southern Rocky Mountains. To determine the effect of range conditions and related factors on sediment production and runoff on three mountain grassland watersheds in western Colorado. Range condition is being measured by means of 20 or more 3-step transects on each watershed. Ninety degree V-notch weirs are used to gage the watersheds which vary in size from 86 to 272 acres. Water samples are taken several times daily during snowmelt and periods of storm runoff for determination of suspended sediment; bedload is measured in the weir ponds.
- (g) On the three Black Mesa watersheds, winter precipitation for the period 1957-63 has ranged from 13 to 39 inches per year. The percentage of runoff varied between 1 and 53%. Summer storms have produced runoff on only 2 years out of the 7 in spite of 5-minute precipitation intensities of 3 inches per hour which have occurred frequently. Ground cover index is significantly related to snowmelt peak discharge but grazing treatments have had slight effect on measured ground cover index. On the Alkali Creek watershed it has been repeatedly observed during prior years that the suspended sediment load of the melt flows is closely related to time since start of melt runoff rather than rate of discharge. Thus, in measurements made during 1964, at station "30 feet below concrete check dam," there was a suspended sediment concentration of 20,700 p.p.m. at a discharge of 8 c.f.s. on April 14, while 2 days later 13,400 p.p.m. were contained in a flow of 19 c.f.s. At station "Mesa-Garfield County Line," on April 15, 63,800 p.p.m. of suspended sediment were sampled in a flow of 79 c.f.s. This decreased to 35,100 p.p.m. on April 16, although discharge was 107 c.f.s. By the last week of May 1964, the flow in all gullies was almost clear. Samples taken in the catch basin of the concrete check dam, at the waterfall of the structure, and 30 feet downstream had sediment concentrations of 13,700 p.p.m., 13,400 p.p.m., and 13,400 p.p.m. respectively. The regimen of the flow is drastically different between these stations so that the close agreement of these samples indicates that true suspension of the sediment existed at the time of sampling. This seems reasonable because analyses gave 97.5 to 98.1% silt and clay in these samples.

(380) WATER RESOURCE AND WATERSHED MANAGEMENT
RESEARCH.

- (b) Laboratory project. For general public use and information.
- (c) Dr. Thomas F. McIntock, Director, Southeastern Forest Experiment Station, U. S. Forest Service, P. O. Box 2570, Asheville, North Carolina. 28802.
- (d) General investigations of forest influences in the southeastern United States, with primary emphasis on fundamental hydrologic research on watershed processes and related application in watershed management.
- (e) Basic research into forest hydrologic processes from the precipitation of water over an area until it leaves the watershed as streamflow or evapotranspiration. Demonstrations of several cover types and land management practices and their effect upon water yield, quality and flow characteristics. Development of watershed management methods pertinent to the region and cooperative trials and demonstrations of these methods. Most of the experimental and hydrologic data are collected on the 5600-acre Coweeta Hydrologic Laboratory, located in the zone of maximum precipitation for the eastern United States (Nantahala Range of the southern Appalachians). The basic hydrologic gaging network at the Coweeta Hydrologic Laboratory, near Franklin, N. C., includes 3 multiple and 12 unit watersheds currently active and 16 standby watersheds on which up to 30 years of continuous streamflow records and a cumulative total of more than 700 years are available on drainages ranging from 4 acres to 8 square miles, 12 recording and 11 standard rain gages, 1 recording hygrothermograph, 1 metering anemometer, 1 evaporation pan, and 1 recording pyrheliometer. Occasional water samples are collected from selected watersheds for quality analysis on a storm period basis. Soil moisture is measured in the field with 3 neutron scattering devices servicing a network of some 77 access tubes. A small laboratory equipped for instrument repair and soil and plant physical analysis now includes a dew point hygrometer. Most recording devices are of the chart-trace type with exception of 14 analog-to-digital streamflow recorder. Streamflow data are being reduced from chart traces to punch cards by an Oscar-K chart reader with subsequent computation and analysis by computers at the National Weather Records Center in Asheville, N. C., and at the University of Georgia, Athens, Ga. Supplementing the plant-soil-water studies at Coweeta is a research unit located in the piedmont at Union, S. C. Now largely inactive, these research facilities include 4 unit watersheds and installations for studying comparative water use by cover types and soil moisture recharge. Research studies include: (1) a review of the relation of rain gage catch to actual precipitation on steep forested watersheds; (2) incident solar radiation on forested and cleared slopes; (3) effect of forest cover and mountain physiography on the radiant energy balance; (4) increasing water yield by nondestructive transpiration control; (5) distribution of roots of common forest trees in the southern Appalachians; (6) movement and storage of soil water on steep slopes; (7) rainfall interception by white pine; (8) predicting soil moisture in steep terrain for hydrologic purposes; (9) morphology of the soil mantle related to moisture storage and movement; (10) the effect of forest cutting on water yield; (11) the hydrology of mountain unit watersheds under several cover types; (12) mechanizing streamflow data collection and computing; (13) stream diversion on a steep forested slope to stabilize and increase late summer

yield; (14) source, volume, and timing of streamflow from mountain watersheds, (15) a regional study of the small watershed hydrograph based on records from Coweeta, Bent Creek, Union, and Fernow, and (16) a pilot study testing multiple uses such as water, timber, recreation, and wildlife on a 360-acre watershed. Research by personnel of the Wetland Improvement Project at Charleston, South Carolina is developing effective water control practices to improve productivity of wetland forest soils of the southeastern coastal plain and evaluating effects of these practices on wetland hydrology and soils. Accordingly, much of the program consists of drainage studies in cooperation with National Forests, wood-using industries, and other wetland forest managers who have made or plan capital investments to drain their land. In addition, research is also being conducted on the Santee Experimental Forest, located 32 miles north of Charleston, which has a small soils laboratory and two stream gaging stations on watersheds of 400 and 8,000 acres. Active studies include: (1) response of wet, slash pine flats to drainage; (2) relationships between soil and water conditions and to tree response on drained wetlands; (3) study of the water-balance of selected wetland units; (4) evaluation of the drainage state of representative wetland sites; and (5) precipitation-runoff relations on small forested watersheds in the coastal plain.

(g) The 22-acre watershed converted in 1960 from hardwood to grass has shown small increases in streamflow since 1961. These increases apparently are related to dry matter production as the dense fescue cover developed after heavy initial fertilization has gradually thinned out. This hypothesis will be tested when the grass is heavily refertilized in 1965 to return dry matter production to 1960 levels. A grass covered soil column 4.5 feet wide, 7 feet deep, 200 feet long, and inclined at 38 percent has been allowed to recharge and deplete naturally. Both recharge and depletion are more rapid than on a nearby small forested watershed, indicating less storage capacity in the plastic-lined soil column. During 1964, evapotranspiration from the soil column was 26.5 inches, only 1 inch less than potential as calculated by the Thornthwaite method. A review of all available hardwood interception studies shows that throughfall does not differ materially among mature hardwoods of eastern United States. Stemflow is greatest on smooth-barked trees, least on older, rough-barked trees. Fragmentary documentation shows litter losses about 2-4 inches annually with possibility of much higher losses under very warm or much colder climates. Analysis of rainfall data at Coweeta indicates that gage site selection with reference to wind speed is critical to both accuracy and precision of precipitation sampling. The natural shielding provided by 45° openings in the dense native forest usually provides suitable samples if problem areas such as exposed ridges, gaps, and lee sides of peaks are avoided as gage sites. Helicopter application of a transpiration retardant (5 gallons per acre of .01 m glyceryl succinic acid) along the riparian zone of a calibrated watershed did not affect diurnal stream fluctuation nor did it influence total water yield. A pilot study shows that intensive multiple use management is economically feasible but that large storms increase sediment loads in streams even when logging is very carefully done. Gravimetric methods of calibrating neutron probes has been found to underestimate the true slope of the calibration curve. A volumetric calibration process was developed in which the standard error of calibration was less than four counts per each percent soil moisture by volume. Volumetric calibration gave more accurate estimates of

moisture changes than previously used gravimetric calibration curves. Recent research results from Charleston indicate shallow collection ditches have little additional impact on ground water levels during dry years beyond that created by the main ditches. They expedite the removal of water from the ground surface and upper soil layers in wet periods when water levels are high. It does not appear that a 5-chain spacing of shallow collection ditches in fine sandy soils underlain by sandy clay will result in over-drainage of the site for young slash pine trees.

- (h) "Test of a Transpiration Inhibitor on a Forested Watershed," by P. E. Waggoner and J. D. Hewlett, to be submitted to Journal of Geophysical Research.
- "DDT Residues in Mountain Stream Waters as Influenced by Treatment Practices," by A. R. Grzenda, H. P. Nicholson, J. I. Teasley, and J. H. Patric, Journal of Economic Entomology 57(5): 615-618, 1964.
- "Ground Water: Definition," by J. D. Hewlett, Science 144(3625): 1407, 1964.
- "Water Absorption by Deep Rooting Forest on Plastic-Covered Mountain and Piedmont Soils," by J. H. Patric, J. E. Douglass, and J. D. Hewlett, in press, Soil Science Society of America Proceedings.
- "Research in Hydrology of Forested Watersheds at the Coweeta Hydrologic Laboratory," by J. D. Hewlett, Proceedings, 29th Meeting of the North American Wildlife and Natural Resource Conference, Las Vegas, 1964.
- "Seasonal Water Absorption by Deep Rooting Forest Trees on Plastic-Covered Mountain and Piedmont Soils," by J. H. Patric and J. E. Douglass, Proceedings of the Soil Science Society of America Meeting at Denver, 1963.
- "Rainfall Interception by Hardwood Forest Litter in the Southern Appalachians," by J. D. Helvey, U. S. Forest Service Research Paper SE-8, 1964.
- "Canopy and Litter Interception of Rainfall by Hardwoods of Eastern United States," by J. D. Helvey and J. H. Patric, to be submitted to Water Resources Research.
- "Volumetric Calibration of Neutron Probes," by J. E. Douglass, to be submitted to Soil Science Society of America Proceedings.
- "Water on Forest: How can we Have all we Need of Both," by J. D. Hewlett, in press.
- "Water Management: Key to Wetland Forest Improvement in the Southeast," by C. E. Young, Jr., to be published in Proceedings of American Society of Agricultural Engineers.
- "Water Tupelos Like it Wet," by R. A. Klawitter, 1964 Christmas Issue, Southern Lumberman.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
Southern Forest Experiment Station.

Inquiries concerning the following projects should be addressed to Mr. W. M. Zillgitt, Director, Southern Forest Experiment Station, T-10210 Federal Bldg., 701 Loyola Avenue, New Orleans, Louisiana 70113.

- (2914) WATERSHED MANAGEMENT RESEARCH, OXFORD, MISSISSIPPI.
- (b) Laboratory project, in cooperation with Soil Conservation Service, Agricultural Research Service, and University of Mississippi.
- (d) Field investigation of runoff and erosion from small experimental watersheds on forest and potential forest lands; basic and applied research.
- (e) Twelve small natural headwater catchments, two to four acres each, were installed in batteries of three to determine runoff and erosion from old fields, depleted upland hardwoods, pine plantations, and mature upland pine-hardwoods. Four of the six old field and depleted hardwood watersheds were planted to pine in 1964, after site preparation which included burning. Treat-

ments on the pine and pine hardwoods are deferred until after a suitable calibration period. Five additional watersheds in pine plantations are being calibrated prior to testing effects of timber harvesting on runoff, erosion, and sediment flows. Related studies include restoration of depleted watersheds and plant-soil-water relationships.

- (f) Data collection on all watersheds is continuing.
- (g) Runoff and erosion appear to have increased moderately after prescribed burning.
- (h) "Low-Cost Rain Gage Improved," Thomas L. Rogerson. Journ. Soil and Water Conserv. 19(4): 157-158, illus., July-August 1964.
- "Water Stage Recorder Wells Protected From Freezing by Homemade Candles," N. C. Bennett and D. C. McClurkin. Agr. Engin. 45(6): 330, illus., June 1964.
- "Research to Tame the Rain," George K. Stephenson. U. S. Forest Serv. South. Forest Expt. Sta., 15 pp., illus. 1964.
- "Refrigerator-Car Storage of Loblolly Pine Seedlings Highly Successful," H. L. Williston. U. S. Forest Serv. Res. Note SO-13, 3 pp., illus. 1964.
- "Seedling Storage in Refrigerator Cars," H. L. Williston. U. S. Forest Serv. Tree Planters' Notes 65, p. 20, 1964.
- (3225) WATERSHED MANAGEMENT RESEARCH, HARRISON, ARKANSAS.
- (b) Laboratory project.
- (d) Field investigations on effects of forest type and condition on timing of flows in streams of the Ozark-Ouachita uplands; basic and applied research.
- (e) Runoff and sediment from three small mountain watersheds are measured currently. H-flumes and stage recorders were installed on eight additional watersheds ranging from 2 to 40 acres. Cover conditions will be changed after an adequate calibration period. Related studies of soil moisture and erosion are continuing.
- (f) Records of runoff and sediment collected currently.
- (h) "Moisture, Pore Space, and Bulk Density Changes in Frozen Soil," A. W. Krumbach, Jr. and D. P. White. Soil Sci. Soc. Amer. Proc. 28(3): 422-425, illus., May-June 1964.

CORPS OF ENGINEERS, U. S. ARMY, Coastal Engineering Research Center.

Inquiries concerning the following projects should be addressed to the Director, Coastal Engineering Research Center, 5201 Little Falls Road, N. W., Washington, D. C. 20016.

- (181) EQUILIBRIUM PROFILE OF BEACHES AND STUDY OF MODEL SCALE EFFECTS.
- (b) Laboratory project.
- (d) Experimental; basic research.
- (e) Equilibrium beach profiles will be determined experimentally for waves up to 6 feet in height in a prototype tank; the waves will be modeled at a 1 to 10 scale in small laboratory tanks (to determine scale effects) for various median diameter and specific gravity sediments.
- (g) Additional tests were made using crushed coal of average specific gravity 1.5 (modeled by the settling velocity relationship to give corresponding characteristics of material tested in the large tank). Observed material movement and profile changes corresponded basically to the large scale results in the prototype tank, although the coal slope deteriorated somewhat faster. A partial explanation for differences is the wide range of specific gravities of individual coal particles. Tests for a few selected storm waves were made in the large tank with waves from 2 to 5.5 feet in height

- using a sand of 0.4-mm. median diameter. The profiles obtained in these tests may be compared with those obtained earlier with 0.2-mm. sand to indicate differences in rates of scour and degree of protection with different sized material. A single test was made simulating a tidal condition.
- (660) OBSERVED WAVE CHARACTERISTICS.
- (b) Laboratory and field project.
 - (d) Field investigation; basic research.
 - (e) To secure a more thorough knowledge of the characteristics of ocean waves. Wave gages have been installed in a number of locations in coastal waters. These wave gages provide electrical recordings and also magnetic tape recordings. The records from the paper chart recorders are analyzed for significant wave height and wave period. The records from the magnetic tape recorders are analyzed to provide a spectral analysis of wave frequency (or period) versus: (1) linear average wave height; (2) squared average wave height; and (3) peak wave height.
 - (g) An additional wave recording station was installed at Daytona Beach, Florida, during 1963. Installation of 3 wave sensors at the Buzzards Bay Light Tower (coast Guard) was delayed due to tower modifications (installation of stainless steel cable gage supports). Installation of the cables and gages is expected during first quarter of 1965. These gages will be used to establish pressure gradient at different water depths. This data will be compared to surface waves as recorded by a surface wave gage. Additional wave recording stations are planned to be installed at: (a) Coast Guard Light Tower, Frying Pan Shoals, (b) Galveston, Texas, and (c) Los Angeles, Calif. (2).
- (975) METHODS OF BY-PASSING SAND PAST INLETS.
- (b) Laboratory project.
 - (d) Field investigation; applied research.
 - (e) To study methods and requirements for pumping sand past inlets and to determine the applicability of the methods in stabilization of beaches adjacent to inlets. Data are being procured on the effect to the shoreline of sand by-passing operations at Port Hueneme, California and Lake Worth Inlet, Fla. and on the effect to the shoreline of a new harbor constructed at Ventura, California. This latter harbor involves an offshore detached breakwater along with entrance jetties to the new harbor. Data at the three locations include periodic hydrographic surveys south and north of the inlet, wave data, sand samples, detailed records of pumping operations, and detailed records of entrance channel maintenance. A general study is being made of the possibility of adapting commercial instruments utilizing a radioactive source to the discharge line to measure quantity of material pumped in by-passing operations.
- (976) ESTABLISHMENT OF CRITERIA FOR CONSTRUCTION OF ARTIFICIAL BEACHES.
- (b) Laboratory project.
 - (d) Theoretical; applied research.
 - (e) To develop criteria for construction of beaches by artificial means. The present continuing phase of this general study involves the measurement of a natural beach slope and attempts to determine its response to the forces normally incident upon the shore such as wave height and period, angle of wave approach, tide, and direction and magnitude of littoral current. By statistical methods the relative importance of the forces or combinations of forces may be evaluated.
 - (g) Computing machine techniques have been applied to the statistical evaluation of the importance of the forces and of the parameters. (2192)
- (977) DEVELOPMENT OF WAVE HEIGHT AND WAVE DIRECTION GAGES.
- (b) Laboratory project.
 - (d) Experimental; development.
 - (g) Three additional wave gages were furnished to the Detroit District, (U.S. Lake Survey). Total gages in this project is now nine (9). Data from these gages are to be used in a wide study of the Great Lakes for pollution control by the Public Health Service. One of the new gages is unique in that it operates from electrical power provided by a thermoelectric generator using propane gas as fuel. An ultrasonic flow meter was checked in the laboratory large wave tank as a wave direction gage. Preliminary data shows good promise of adapting the flowmeter to function as a wave direction gage. Further tests are planned at Atlantic City, N. J. upon procurement of a modified flowmeter. This test is to provide information as to the suitability of this device in an actual measurement condition.
- (2190) STUDY OF EFFECT OF A GROIN ON THE RATE OF LITTORAL MOVEMENT.
- (b) Laboratory project.
 - (d) Experimental; basic research.
 - (e) To study the effect of groins on the rate of littoral drift passing a groin system. Initial tests consist of waves generated at a 30-degree angle to the sand beach with measurement of material movement being made at the downdrift end. The tests planned for the immediate future, as have the current season tests, will continue to emphasize the task of collecting and establishing reliable calibration data on the relationship between the littoral transport rate and the wave characteristics. These generalized (not to specific model scale) studies are being made in the Shore Processes Test Basin of the Coastal Engineering Research Center.
 - (g) Analysis of comprehensive wave height measurements made in the North Sector of the Shore Processes Test Basin indicate the presence of a cross-basin wave. Curve pattern similarities and differences (opposites) from the wave height measurements in different locations of the basin show the effect on the wave height distribution of the cross basin wave and that it has the same wave period as the generated (incident) wave. Comparison of curve patterns representing separate locations in the basin generally show that where the curve patterns at each location are the same type, as a maximum or minimum height at each location, the wave travel time or distance between points of measurement is an even multiple of half wave lengths; conversely, where the wave patterns are of opposite type, as a maximum height at one location and a minimum height at the other location, the wave travel time or distance is equal or very near an odd multiple of half wave lengths. The presence of a cross-basin wave has been fairly well demonstrated by special analyses of the SPTB curves showing wave height distribution with distance. However, this does not explain the variability of wave height at a fixed gage. In order that a cross basin wave of the same period as the generated wave, cause height variability at a fixed gage, it would be necessary that its phase shift slightly with successive generator starts or during wave generation. Although no direct evidence of a cross-wave phase shift with successive generator starts has been observed, in view of the large range of height variability measured, it seems highly improbable that such a phase shift does not actually occur. A slight phase shift has been observed during wave generation from the time or sequence measurements of height variability at a fixed gage.
- (2192) REGIONAL STUDIES OF THE ATLANTIC COAST OF

NEW JERSEY; AND THE DELAWARE-MARYLAND-VIRGINIA SHORE LINE FROM CAPE HENLOPEN TO CAPE CHARLES.

- (b) Laboratory project.
- (d) Field investigations; basic research.
- (e) To compile all existing data pertinent to shore processes on a regional scale. Reports to consist of three chapters: geomorphology and shoreline histories, littoral forces, and littoral materials. Subject matter to include physiography, geological development of the shore region, sources of littoral material, waves, tides or water level fluctuations, current physical characteristics of the littoral materials, interrelation of sedimentary properties, relation of properties of littoral materials to position in the littoral zone, and changes in shoreline configuration.
- (g) The Delaware-Maryland-Virginia shoreline from Cape Henlopen to Cape Charles is currently under study. Data compilation for this reach is essentially completed and the report is under preparation.
- (2193) SHORE PROTECTION PLANNING AND DESIGN.
 - (b) Laboratory project.
 - (d) Design.
 - (e) To supplement and revise the Coastal Engineering Research Center's (formerly Beach Erosion Board) Technical Report No. 4, "Shore Protection Planning and Design" as new data and techniques are developed for use in the solution of coastal engineering problems.
 - (g) The supply of the October 1961 edition of the report has been depleted. It is anticipated that the new edition will be available in the Fall of 1965.
- (2195) RE-EXAMINATION OF ARTIFICIALLY NOURISHED AND CONSTRUCTED BEACHES.
 - (b) Laboratory project.
 - (d) Field investigation; applied research.
 - (e) To study the behavior of beach fills placed to restore or nourish a beach sector and the effect of the fill on adjacent shores. A selected number of beach fills are being re-examined.
 - (g) Follow up report prepared, but not yet published, on beach fill at Seaside Park, Conn. Other reports in preparation for beach fill projects, at Presque Isle, Pa., Sherwood Island State Park, Conn., and Hammonasset Beach State Park, Conn. Arrangements have been made to collect Follow up data for beach fill and nourishment projects in California, Florida, and New Hampshire.
- (2660) STUDY OF QUANTITY OF SEDIMENT IN SUSPENSION IN THE SURF ZONE (INCLUDING TEMPERATURE EFFECTS).
 - (b) Laboratory project.
 - (d) Experimental; basic research.
 - (e) To determine the relationship between wave, water, and sand characteristics, and the amount of material maintained in suspension and, hence, available for longshore transport by currents.
 - (g) A tractor-mounted suspended sand sampler for wave action sampling was developed at CERC laboratory and field tested at Jennette Pier, Nags Head, N. C. More than 400 suspended sediment samples were collected in the field tests at Nags Head, N. C. Most of the samples were collected nearshore in and near the breaker zone. Several samples were collected on the outer bar near the end of the pier, about 600 feet offshore. The samples have been analyzed for weight (concentration) and size distribution. A report describing the development of the suspended sediment sampler with preliminary analysis of the samples collected in the field tests is in preparation.
- (2661) WAVE RUN-UP ON SHORE STRUCTURES.
 - (b) Laboratory project.
 - (d) Experimental; design.
 - (e) Wave run-up is determined experimentally for various waves for different types of shore structures. Effect of both structure roughness and permeability is being investigated.
 - (g) Some field measurements of run-up on a beach were obtained in an attempt to delineate the run-up distribution function. Some model tests also indicate that in a model wave tank measurement of wave action may depend to a significant extent on the location of the measurement point relative to the wave generator, because of the generation of secondary waves and the importance of the phase relation of these to the main waves, which changes with distance of travel.
- (3228) MODEL TESTS OF WAVE SETUP ON BEACHES.
 - (b) Laboratory project.
 - (d) Experimental; basic research.
 - (e) To relate increase in water level at the shore due to wave action alone, to the incident wave characteristics and shore hydrography.
 - (g) See project (5328) "Characteristics of a Plunging Breaker".
- (3897) RADIOACTIVE TRACERS FOR BEACH STUDIES.
 - (b) Laboratory project.
 - (d) Experimental; research.
 - (e) Studies of possible field sites for the application of radioactive and/or fluorescent tracers are being continued.
- (4760) EXPERIMENTAL STUDY OF DUNE BUILDING WITH SAND FENCES.
 - (b) Laboratory project.
 - (d) Experimental; design.
 - (e) The experimental study consists of the construction of various types and arrangements of sand fences to determine the fence type and arrangement most effective in building a dune by trapping and holding wind-blown sand. Slat-type snow fencing and locally constructed brush fencing have been used in straight, straight-with-side spurs, and zigzag configurations. The study is being conducted on the Outer Banks of North Carolina between Cape Hatteras and Cape Lookout.
- (4762) CORRELATION OF STORM WAVE ATTACK AND BEACH EROSION.
 - (b) Laboratory project.
 - (d) Field and office investigation to develop quantitative correlation between storm violence and shore erosion.
 - (e) Repetitive profiles are taken at selected beach areas. The storm wave action between surveys is analyzed and correlations between the wave action and observed profile changes are established. Repetitive profile lines were established in September 1962 at nine locations between Delaware Bay and Cape Cod. These profiles were resurveyed at weekly and bi-weekly intervals. The resurvey interval now is 4 to 6 weeks. Storm wave action is measured by the Coastal Engineering Research Center ocean wave gages and storm surges by U.S.C.&G.S. tide gages.
 - (h) "Seasonal Changes in Beaches of the North Atlantic Coast of the United States", by John M. Darling, Hydraulic Engineer, Research Division, Coastal Engineering Research Center was presented at the IX Coastal Engineering Conference in Lisbon, Portugal, in June 1964. It is being edited by the ASCE and will be published in early 1965.
- (4763) OFFSHORE SAND SOURCES.

- (b) Laboratory project.
 - (d) Field investigation; applied research.
 - (e) Four selected areas along the Atlantic Coast of New Jersey have been explored by geophysical (sonic) methods and by shallow borings. A preliminary dredge feasibility operation has been completed in Chesapeake Bay (Thimble Shoals Channel).
 - (g) It has been determined from preliminary data that the cost of pumping sand to the beach is competitive with conventional sources.
- (5079) WAVE HEIGHT PREDICTION FOR WAVE MAKERS IN SHALLOW WATER.
- (b) Laboratory project.
 - (d) Theoretical and experimental; basic research.
 - (e) By equating the volume of water displaced in half a period by a displacement-type wave maker to the volume of water raised above mean water level in a sine-shaped wave, a simple relation results for shallow water waves which gives wave height as a function of wave length, wave maker stroke, and wave maker geometry. For shallow water, this relation agrees with hydrodynamic theory for piston-type and flap-type wave makers, and with published and unpublished data for waves generated by displacement-type wave makers in absolute water depths ranging from 0.5 feet to 13 feet.
 - (f) Completed.
 - (g) The height of wave generated by displacement-type wave makers in shallow water is approximately equal to $2\pi S/L$ times an appropriate dimension of the wave maker. S is the stroke of the wave maker, L is the wave length given by small amplitude theory, and the wave maker dimension is measured perpendicular to the direction of S . This relation agrees with the hydrodynamic theory for piston and flap-type wave makers over the range of depths usually used in coastal engineering experiments, and it is supported by data from 4 piston-type and 2 plunger-type wave makers for depths satisfying the condition $\frac{2\pi d}{L} < 1$.
 - (h) "Wave-Height Prediction for Wave Generators in Shallow Water", C. J. Galvin, Jr., U. S. Army Coastal Engineering Research Center, Technical Memorandum No. 4, March 1964, 21 pp.
- (5082) EFFECTIVENESS OF LOW CRESTED OR SUBMERGED BREAKWATERS.
- (b) Laboratory project.
 - (d) Experimental; applied research.
 - (e) To determine the relative effectiveness of low-crested and submerged rubble mound breakwaters. Measurements have been made in the laboratory of the transmission of wave energy over and through both permeable and impermeable rubble mound breakwaters of varying crest width, crest elevation, and water level elevation. Tests were made at both small scale (maximum 6" wave) and large scale (maximum 4-foot wave).
 - (g) Variation in crest width had much less effect in reducing transmitted wave height than did crest elevation. Effectiveness of impermeability of breakwater decreases with higher waves, and particularly with higher water levels.
 - (h) Final report furnished Navy Bureau of Yards and Docks, Southwest Division.
- (5325) FIELD MEASUREMENT OF LONGSHORE CURRENT VELOCITY.
- (b) Laboratory project.
 - (d) Field investigation.
 - (e) Longshore current velocity was measured by timing the travel of water filled balloons in the surf on the beach near Nags Head, N. C.; breaker angles were measured with a Brunton compass, by triangulation and by measuring the speeds of the crest and plunge point of the breaking wave; beach slope was obtained from profiles through the surf zone; and wave heights and periods were measured from wave gage records.
 - (f) Suspended.
 - (g) For the five sets of data obtained, longshore current velocity, V , is roughly predicted by the equation, $V = \frac{gmT\sin 2\theta_b}{2\pi}$, where m is beach slope, g acceleration due to gravity, θ_b is the breaker angle, and T is the wave period.
- (5326) RESONANT EDGE WAVES ON LABORATORY BEACHES.
- (b) Laboratory project.
 - (d) Experimental.
 - (e) An unusual standing wave in the runup on laboratory beaches is under study. The combinations of slope, period, breaker type, standing wave length, and resonant amplification are being measured in order to describe the phenomena and to understand its affect on laboratory and natural beaches.
 - (g) The run-up from lightly plunging or surging waves occasionally resonates between the sidewalls of a wave tank 1.5 ft. wide. The resonant period is twice the period of the waves reaching the beach. Whenever the resonance is present on the plane beach, it always has a resonant period, beach slope, and tank width (1.5') which fits the equation for resonant edge waves. When this resonance occurs on a sand beach 40 feet wide, it occasionally produces cusps whose spacing is one-half the edge wave length. The width of the sand beach is not necessarily an integral multiple of the cusp spacing.
 - (h) "Cusps Formed by Standing Edge Waves on a Laboratory Beach", C. J. Galvin, Jr., program 1964 Annual Meeting of Geological Society of America, p. 69.
- (5327) THE EFFECT OF SECONDARY WAVES ON WAVE RUN-UP.
- (b) Laboratory project.
 - (d) Experimental; basic research.
 - (e) This project was begun to learn the cause of certain peculiarities in the variability of wave run-up with wave period and height on steep slopes. Run-up tests were made in a 2' x 1-1/2' x 72' wave tank on smooth slopes installed at various locations along the tank. Slopes varied from 1:15 to 1:6. Each slope was tested in three water depths (0.65, 0.90, and 1.25 feet) in an attempt to determine the effect of water depth on the wave run-up.
 - (g) It was learned from an analysis of the tests that a strong correlation exists relating the phase angle between the primary and secondary waves and the height of wave run-up. The run-up for a given wave condition is a maximum if the primary and secondary waves are 180° out of phase (i.e. if the secondary wave is in the trough of the primary wave) and a minimum when the two waves are in phase. This variable phase relationship of primary and secondary waves causes the run-up to vary up to a factor of 3 for steep slopes. For flatter slopes (about 1:6) this effect had essentially disappeared.
- (5328) CHARACTERISTICS OF A PLUNGING BREAKER.
- (b) Laboratory project.
 - (d) Experimental and theoretical, basic research.
 - (e) The wave height, mean water depth, and distance traveled in the breaking process are being measured for waves which break by plunging on a plane concrete beach in a wave tank 96 feet long and 1.5 feet wide. Parallel wire resistance wave gages measure the wave heights, damped piezometers buried flush with the beach surface measure the mean water level and photographs record the distance traveled in breaking. This study is undertaken to increase knowledge of the breaking process, to relate the energy flux of the incoming waves to the resulting wave setup, and to provide engineering criteria for the design of coastal structures.
 - (g) Analysis indicates that the depth at which a

wave initially becomes unstable is probably directly proportional to wave height, but that the relation between breaker depth-to-height ratio and slope is an apparent one due to the wave moving into shallow water before wave deformation has progressed far enough for breaking conditions to be defined. From these considerations, it can be predicted that between the initial instability and the defined breaking point is a horizontal distance approximately equal to 4.5 times the breaking wave height, and that between the defined breaker position and the point where the plunge of the wave is complete is approximately equal to 2 times the breaking wave height. Preliminary measures of the breaker depth-to-height ratio and the horizontal distance traveled by waves plunging on a 1:10 slope are in fair agreement with this analysis.

U. S. ARMY ENGINEER DISTRICT, CORPS OF ENGINEERS, Portland.

Inquiries concerning Projects Nos. 406, 4504, 5068, 5069, 5070, 5071, 5315, 5316, and 5318 should be addressed to the District Engineer, U. S. Army Engineer District, Walla Walla, Building 602, City-County Airport, Walla Walla, Wash. 99362.

- (406) MODEL STUDY OF SPILLWAY AND STILLING BASIN FOR ICE HARBOR DAM, SNAKE RIVER WASHINGTON.
 - (f) Completed
 - (h) "Spillway and Stilling Basin for Ice Harbor Dam," U. S. Army Engineer Division Hydraulic Laboratory, Bonneville, Oregon. Tech. Report No. 31-1, December, 1964. (Available on loan). Final report covering the test results.
- (1465) MODEL STUDY OF SPILLWAY AND STILLING BASIN FOR THE DALLES DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.
 - (c) District Engineer, U. S. Army Engineer District, Portland, 628 Pittock Block, Portland, Ore. 97205.
 - (f) Completed.
 - (h) "Spillway and Stilling Basin for the Dalles Dam," U. S. Army Engineer Division Hydraulic Laboratory, Bonneville, Oregon. Tech. Report No. 55-1, November, 1964. (Available on loan). Final report covering the test results.
- (3231) MODEL STUDY OF OUTLET WORKS AND STILLING BASIN FOR COUGAR RESERVOIR, SOUTH FORK MCKENZIE RIVER, OREGON.
 - (c) District Engineer, U. S. Army Engineer District, Portland, 628 Pittock Block, Portland, Ore. 97205.
 - (f) Completed.
 - (h) "Outlet Works and Stilling Basin for Cougar Reservoir, South Fork McKenzie River, Oregon," U. S. Army Engineer Division Hydraulic Laboratory, Bonneville, Oregon. Tech. Report No. 87-1, May 1964. (Available on loan). Final report covering the test results.
- (4504) GENERAL MODEL STUDY OF LITTLE GOOSE LOCK AND DAM, SNAKE RIVER, WASHINGTON.
 - (b) U. S. Army Engineer District, Walla, Corps of Engineers, Walla Walla, Washington.
 - (d) Experimental; for design.
 - (e) A fixed-bed model constructed to an undistorted scale ratio of 1:100 reproduces the Snake River bed and pertinent overbank topography between river miles 68.3 and 71.6. The dam axis is at mile 70.3. The original layout consists of a straight, 8-bay, gravity-type spillway controlled by 50-by 53-ft tainter gates, a powerhouse for six Kaplan turbines (initial installation three units), an 86-by 675-ft navigation lock having a maximum lift of 101 ft, concrete nonoverflow sections, rockfill abutments, and facilities for passing migratory fish over the dam. The initial power installation will produce 405,000 kilowatts. Purposes of the model are to check the structures layout and flow conditions affecting cofferdam placement, power generation, navigation, and fish passage.
 - (g) Following tests of various cofferdam layouts, the original structure and excavation plan (with maximum excavation in tailrace and downstream navigation lock approach) was studied. Investigations with minimum downstream excavation and maximum erosion in the spillway exit channel are in progress.
- (4506) MODEL STUDY OF FINGERLING COLLECTOR FOR GREEN PETER DAM, MIDDLE SANTIAM RIVER, ORE.
 - (b) U. S. Army Engineer District, Portland, Corps of Engineers Portland, Oregon.
 - (c) U. S. Army Engineer District, Portland, Corps of Engineers, 628 Pittock Block, Portland, Oregon 97205.
 - (d) Experimental; for design.
 - (e) Two undistorted hydraulic models are being used for studies of facilities for downstream migrant fingerling salmon and steelhead trout at Green Peter Dam. The proposed facility is composed of an entrance horn, vertical adjustable-height riser, separator, flow distribution control device, trough, flexible hose, transverse pipe system, and outlet pipe followed by a flume into the tailwater. The collector will be located on the upstream face of the dam at the focal point of reservoir discharge. Its 20-ft-high horn will collect fish near the water surface with a minimum submergence over its top of 5 ft and a maximum submergence at its bottom of 40 ft. About 200 cfs will enter the horn and carry migrating fish inward, upward, and across a separator screen (a 10-by 20-ft perforated plate) covering the compartmented flow distribution device through which from 190 to 194 cfs will pass vertically into a collector well and then be pumped back to the reservoir. Fish in the remaining 6 to 10 cfs will be carried from the separator screen through a flexible hose attached to laterals through the dam and thence by open channel flow to the tailrace. A trash boom at the upstream face of the dam will prevent small floating and suspended debris from entering the fingerling collector.
 - (f) Tests have been completed.
 - (g) Two-ft-wide sections of prototype and model separator plates were tested in a flume model as the first step in determining model-prototype similitude relationships. The model perforated plate that reproduced flow conditions over the prototype plate in the most satisfactory manner was used in a 1:4-scale model of the entire fingerling collector. Tests of different distributor bar spacings, trough designs, deflector locations, and separator slopes were made in the 1:4-scale model.
 - (h) Final report is in preparation.
- (5068) MODEL STUDY OF SPILLWAY FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON.
 - (b) U.S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Washington.
 - (d) Experimental; for design.
 - (e) The 1:42.47-scale model includes a 3-bay section of the 8-bay spillway and stilling basin. Tests are being made to evaluate hydraulic performance of the proposed spillway and to develop revisions in design that would increase performance or reduce construction and maintenance costs.
 - (g) Pressures, head-discharge relationships, and pier contraction coefficients were determined for free flow over the crest and for unequal openings of adjacent crest gates. Although an acceptable design for a horizontal stilling

basin was derived in the model, protection against unusual amounts of artesian water underneath the concrete apron will greatly increase construction costs if a conventional stilling basin is adopted. Attempts to eliminate the stilling basin paving through use of a conventional roller-type bucket were not satisfactory. Tests are in progress to determine whether satisfactory hydraulic conditions and minimum downstream erosion can be obtained with a slotted or dentated roller-type bucket.

(5069) MODEL STUDY OF LITTLE GOOSE NAVIGATION LOCK, SNAKE RIVER, WASHINGTON.

- (b) U.S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Washington.
- (d) Experimental; for design.
- (e) A 1:25-scale model reproducing the intake manifolds, 86-ft-wide by 675-ft-long lock chamber, split lateral filling and emptying system, outlet culverts, and portions of adjacent approach and outlet areas is being used to check the suitability of the original design and to develop improvements if needed. An alternative method for distributing flow to the lateral culverts through a central junction chamber is being studied in a separate 1:25-scale model.

(g) Satisfactory designs for all elements of the structure were developed. The lock chamber can be filled in 11.5 minutes and emptied in 12.8 minutes under an initial head of 101 feet through a split lateral hydraulic system. Maximum hawser forces on an 8-barge tow completely filling the lock will average about 5 tons. After numerous revisions, good flow distribution was obtained in the junction chamber model. This hydraulic system was not tested in the comprehensive model. Tests of the final design lock are scheduled for completion early in 1965.

(5070) MODEL STUDY OF SPILLWAY FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.

- (b) U.S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Washington.
- (d) Experimental; for design.
- (e) An undistorted, 1:50-scale, fixed-bed model reproduces the river bed and pertinent overbank topography for about 3600 feet upstream and downstream from the project axis. Presently installed are the cofferdams, diversion tunnel, tunnel outlet channel, and temporary fishway entrance. Later the forebay height will be increased to reproduce the 673-ft-high dam, and the spillway, stilling basin, regulating outlets, and fish facilities will be installed for tests of these elements.

(g) Verification was completed. The 40-ft horseshoe-shaped tunnel and cofferdam were installed and the study of flow conditions during diversion were begun. Tests indicated that flow conditions were improved by relocating the tunnel entrance and realining the tunnel and downstream approach. Studies were made to determine the best method of dissipating energy at tunnel portal in order to provide satisfactory conditions for log passage and fish attraction. Investigation of method to be used in sealing diversion tunnel is in progress.

(5071) GENERAL MODEL STUDY OF LOWER GRANITE LOCK AND DAM, SNAKE RIVER, WASHINGTON.

- (b) U.S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Wash.
- (d) Experimental; for design.
- (e) An undistorted, 1:100-scale, fixed-bed model will reproduce the Snake River bed and pertinent overbank topography for 1.4 miles upstream and 1.7 miles downstream from the project axis (107.5 river miles upstream

from the junction of the Snake and Columbia Rivers). Studies will be made to determine flow conditions during successive construction stages and after proposed structures have been installed.

- (g) Verification tests were completed. Model tests of the original first-stage cofferdam plan are in progress.

(5072) TESTS OF RUBBER TAINTER GATE SEALS, LIBBY DAM (MONTANA) AND DWORSHAK DAM (IDAHO) PROJECTS.

- (b) U.S. Army Engineer District, Seattle, Corps of Engineers, Seattle, Wash.
- (c) District Engineer, U. S. Army Engineer District, Seattle, 1519 South Alaskan Way, Seattle, Wash. 98134.
- (d) Experimental; for design.
- (e) Tainter-type sluice valves planned for the regulating outlets at Libby and Dworshak Projects will operate under maximum heads greater than 260 feet. Because such heads are unusually high for this type of gate, sealing and deformation tests on rubber side seals for the gates were considered necessary.

(f) Completed.

(g) Three-foot-long specimens of Teflon-clad and unclad rectangular rubber seals and a Teflon-clad, rounded-bulb "J" seal were tested under 300 ft of head in a 1:1-scale pressure tank. The test seals were of natural rubber having a durometer index of about 65. With a gap of 1/8 inch between the Teflon-clad rectangular seal bulb and the seal plate, the seal closed against or retracted from the seal plate at pressures less than 5 psi. Almost the entire 1-1/2-inch face of the seal bulb contacted the seal plate under 300 ft of head. The downstream corner of the seal protruded 1/8-inch into a 3/8-inch gap between the retainer bar and seal plate after the first 10 days of a 30-day test. No further deformation occurred, and the seal regained its original shape within an hour after removal from the pressure chamber. Clearance between the seal bulb and seal plate was increased from 1/8 to 1/4 inch and constant-pressure time was reduced from 30 to 15 days for tests of unclad rectangular and Teflon-clad rounded-bulb seals. Seating and retracting heads were slightly higher with the rounded-bulb seal, and semi-permanent deformation of this seal was noted 6 days after the 15-day test was concluded. Performance of all three seal types was considered satisfactory under the conditions tested.

(h) No final report is planned. The test results will be included in the final report for Dworshak spillway.

(5315) MODEL STUDY OF REGULATING OUTLETS FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.

- (b) U. S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Wash.
- (d) Experimental; for design.
- (e) With the spillway gates closed, or with pool level below the spillway crest, reservoir outflows will be controlled by three 9- by 12.5-ft tainter gates located near the upstream end of separate conduits at elevation 1350. Head on the conduits will vary from 95 feet at minimum pool elevation 1445 to slightly more than 250 feet at maximum pool elevation 1601. The outlet conduits will discharge onto the spillway chute at about elevation 1150. Total outlet capacity will vary from 28,300 cfs at minimum pool to approximately 40,000 cfs at maximum pool. Pressures, flow conditions, and discharge relationships will be checked in a 1:25-scale sectional model that reproduces a portion of the forebay, an outside conduit (with streamlined entrance and center line angled 5° - 38' to

- head wall), and a section of spillway downstream from the conduit outlet.
- (g) Model design and construction are in progress.
- (5316) MODEL STUDY OF FISH LADDER FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON.
- (b) U. S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Wash.
- (d) Experimental; for design.
- (e) A 1:10-scale model was used for tests of the 24-ft-wide, 1-on-10 sloped fish ladder for Little Goose Dam.
- (f) Scheduled tests have been completed.
- (g) Velocities, flow patterns, and discharge relationships were determined for typical weirs, orifice control section, and slot-type fish counting station.
- (5317) MODEL STUDY OF COLUMBIA RIVER, OAK POINT TO VANCOUVER, WASHINGTON.
- (b) U. S. Army Engineer District, Portland, Corps of Engineers, Portland, Oregon.
- (c) District Engineer, U. S. Army Engineer District, Portland, 628 Pittock Block, Portland, Oregon 97205.
- (d) Experimental; for design.
- (e) A 40-ft-deep by 600-ft-wide navigation channel between Columbia River miles 52 and 109 and from the Willamette River mouth to Portland, Oregon was authorized recently. Five separate movable-bed models, with 1:300 horizontal and 1:100 vertical scales, will be required to cover improvements in the Columbia River. The models will be used initially to check plans for constructing and maintaining the 40-ft channel. During these studies the location and need for pile dikes, channel alignment and location of spoil areas will be investigated. Later the models will be useful on a continuing basis to check operation and maintenance activities and new construction.
- (g) Design and construction of the first model, between Columbia River miles 64 and 78, was completed and construction of the second model (miles 52 to 65) was begun. Verification tests of the first model were begun.
- (5318) MODEL STUDY OF POWERHOUSE SKELETON UNIT FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.
- (b) U. S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Washington.
- (d) Experimental; for design.
- (e) Owing to an accelerated schedule for completing construction of the John Day powerhouse, it is proposed to place as much of the draft tube concrete as diversion requirements will allow. The proposed skeleton bay interior would be much different from the present contract plans and from that at The Dalles Dam, which is the only unit that has been model tested. Tests of the contract plan and proposed skeleton unit will be made in a 1:25-scale model.
- (g) Design and construction of the model are in progress.
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- U. S. ARMY ENGINEER DISTRICT, CORPS OF ENGINEERS, St. Paul.
- (194) A STUDY OF METHODS USED IN MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS.
- U. S. Army Engineer District, St. Paul and U. S. Geological Survey, in cooperation with St. Anthony Falls Hydraulic Laboratory. See St. Anthony Falls Hydraulic Laboratory, page 76.
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- U. S. DEPARTMENT OF COMMERCE, BUREAU OF PUBLIC ROADS.
- (856) HYDROLOGY OF STORM DRAINAGE SYSTEMS IN URBAN AREAS.
- Cooperative with the Johns Hopkins University. See page 43.
- (2435) HYDRAULICS OF PIPE CULVERTS.
- Cooperative with the National Bureau of Standards. See page 160.
- (2839) HYDRAULICS OF RIVER FLOW UNDER ARCH BRIDGES.
- Cooperative with Purdue University. See page 69.
- (3597) CORRUGATED PIPE ROUGHNESS STUDY.
- Cooperative with U. S. Army Engineer Waterways Experiment Station. See page 192.
- (3805) INVESTIGATION OF SUPERCRITICAL FLOW CHANNEL JUNCTIONS.
- Cooperative with Oregon State College. See page 63.
- (4101) UNSTEADY FREE SURFACE FLOW IN A LARGE STORM DRAIN.
- Cooperative with Colorado State University. See page 17.
- (4617) MECHANICS OF LOCAL SCOUR.
- Cooperative with Colorado State University. See page 19.
- (5533) USE OF LARGE ROUGHNESS ELEMENTS FOR HYDRAULIC ENERGY DISSIPATION.
- Cooperative with Virginia Polytechnic Institute. See page 93.
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- U. S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, Hydraulics Section.
- (2435) HYDRAULICS OF PIPE CULVERTS.
- (b) Bureau of Public Roads.
- (c) Mr. John L. French, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
- (d) Experimental; applied research.
- (e) To determine hydraulic characteristics of various types of culvert entrances and to develop inlets of improved design.
- (h) Author's closing discussion of "Tapered Inlets for Pipe Culverts," by John L. French, Proc. ASCE, Vol. 90, Journal of Hydraulics Div., No. HY2, March 1964. (In press).
- (2436) FLOW OVER HYDROPHOBIC MATERIALS.
- (b) Office of Naval Research, Dept. of the Navy.
- (d) Experimental; applied research.
- (e) To evaluate the increased dissipation at the air - water interface due to a hydrophobic condition of the surface of partially immersed plates oscillating vertically.
- (h) "Friction at Menisci on Hydrophobic Surfaces" by G. H. Keulegan and M. R. Brockman (being revised).
- (4400) MOTION AROUND A BODY IN A STRATIFIED FLUID.
- (b) Office of Naval Research, Dept. of the Navy.
- (c) Mr. Karl Lofquist, Physicist, National Bureau of Standards, Washington, D. C. 20234.
- (d) Theoretical and experimental; basic and applied research.
- (e) A study is made of the internal waves produced

by the horizontal motion of spheres through a stably stratified liquid.

(4891) WAVE PROPAGATION IN A TURBULENT LIQUID.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. G. Kulin, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
- (d) Experimental; basic research.
- (e) A study is being made of additional gravity wave damping due to turbulence.
- (h) Report in preparation.

(4892) TURBULENT SHEAR FLOW THROUGH COMPLIANT WALLED TUBES.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. G. Kulin, Hydraulic Engineer.
- (d) Experimental; basic research.
- (e) Investigation of effect of compliancy of boundaries on a turbulent flow with a view toward possible damping of turbulence and potential reduction in wall shear stress.
- (f) Experimental work completed.

(5252) WIND ACTION ON PRE-EXISTING WAVES.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. G. Kulin, Hydraulic Engineer.
- (d) Experimental; basic research.
- (e) Investigation of effect of a following wind on a mechanically produced swell, with emphasis on changes in wave damping and on hydraulic roughness of the resulting surface.
- (f) Experiments in progress.

(5613) RESPONSE OF A DENSITY-STRATIFIED LIQUID TO A SOURCE OR SINK IMPULSE.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Mr. Karl Lofquist, Physicist, National Bureau of Standards, Washington, D. C. 20234.
- (d) Theoretical and experimental; basic research.
- (e) A study of the internal waves produced by the sudden inflation or contraction of a small spherical membrane situated within stratified liquid.
- (f) Just initiated.

(5614) INTERACTION BETWEEN LONG WAVES AND SUPERPOSED SHORT WAVES.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. G. Kulin, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
- (d) Experimental; basic research.
- (e) Investigation of the change of form of the shorter waves, and of the effect, if any, on damping of the longer waves.
- (f) Just initiated.

(5615) INTERCOMPARISON OF TOWING TANK AND WATER TUNNEL CALIBRATIONS OF CURRENT METERS.

- (b) Laboratory project.
- (c) Mr. John L. French, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
- (d) Experimental; basic and applied research.
- (e) Investigation of wall interference and turbulence effects on current meter calibrations in water tunnels.
- (f) Apparatus under construction.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU.

Inquiries concerning the following projects, except as indicated, should be addressed to Mr. William E. Hiatt, Director of Hydrology, Weather Bureau, U. S. Dept. of Commerce, Washington, D. C. 20235.

(1015) MEASUREMENT OF EVAPORATION.

- (b) Laboratory project.

(d) Theoretical and field investigation; applied research.

(e) Studies are directed toward the derivation of reliable procedures for estimating evaporation from reservoirs (existing and proposed) and land surfaces, utilizing readily available meteorological data and pan evaporation observations.

(g) Research continued on the development of a realistic soil moisture accounting model to provide an improved method for computation of runoff from rainfall in river forecasting operations. The latest model is in the final phase of testing on several basins with different rainfall-runoff characteristics. In compliance with the recommendation of the World Meteorological Organization (WMO) Commission for Instruments and Methods of Observation, an installation has been completed at the Weather Bureau's Test and Evaluation Laboratory at Sterling, Virginia, for comparison of Class A, BPI and insulated experimental evaporation pans with the Soviet GGI-3000 and 20m² evaporation tanks. GGI-3000 tanks were purchased directly from the Soviet Union. The 20m² tank was built according to specifications provided by the WMO. The 20m² tank is approximately 17 feet in diameter and over 6 feet deep, made of 1/4-inch boiler plate and is installed in the ground. The GGI-3000 tank is about 2 feet in diameter and 2 feet deep and is installed in the ground. Observations started in August 1964. It is hoped to make a similar installation in an area with a significantly different climatic regime. The joint project of the Weather Bureau and Forest Service (Intermountain Forest and Range Experiment Station) to study the effects of elevation, aspect and exposure on evaporation has completed the third year of observations. The project consists of 13 Class A evaporation pan stations installed at various elevations (4300 to 9000 feet) on the windward and lee slopes of the Wasatch Range near Farmington, Utah. The data have been punched on cards and are being analyzed.

(h) "Simulation of Daily Catchment Water Balance," by M. A. Kohler, presented and published in Proceedings of National Symposium on Water Resources, Use and Management, held at Canberra, Australia, September 9-13, 1963.

(1744) DEVELOPMENT OF RIVER FORECASTING METHODS.

(b) River Forecast Centers for: Lower Ohio River Basin, Cincinnati, Ohio; Upper Ohio River Basin, Pittsburgh, Pa.; Susquehanna and Delaware River Basins, Harrisburg, Pa.; Missouri River Basin, Kansas City, Mo.; Columbia River Basin, Portland, Oreg.; Middle and Upper Mississippi River Basin, St. Louis, Mo.; Arkansas and Red River Basins, Tulsa, Okla.; New England and Hudson River Basins, Hartford, Conn.; South Atlantic and East Gulf River Basins, Augusta, Ga.; West Gulf Drainage Basins, Ft. Worth, Tex.; Middle Atlantic River Basins, Washington, D.C., and California Drainage Basins, Sacramento, Calif.

(d) Theoretical and field investigation; operation and applied research.

(e) The purpose of these investigations is to develop modern river forecast procedures for all ranges of flow for various streams of each basin. Procedures include: (1) Rainfall-runoff relations involving consideration of the physics of soil moisture, vegetative reception, transpiration, evaporation and geological features of the basins; (2) snow-melt forecasting relations involving consideration of the physics of snow and heat transfer; (3) unit hydrographs; and (4) streamflow routing procedures, based upon adaptations of basic hydraulic principles, using electronic or mechanical analogues.

(g) Forecasting procedures have been developed for key points. Refinement and modification

owing to reservoir construction, channel improvements and other changes are a continuing project. The IBM 1620 computer is being used effectively for operational river forecasting at the Ft. Worth, Kansas City, Sacramento, Portland and Washington, D. C. River Forecast Centers. Efforts are being made to incorporate the decision-making aspects of river forecasting in the operational computer programs.

(1745) WATER SUPPLY FORECASTS FOR UNITED STATES.

- (b) Work being conducted in following field offices: River Forecast Center - Portland, Oreg., Water Supply Forecast Unit - Salt Lake City, Utah, River Forecast Center - Kansas City, Mo., River Forecast Center - Sacramento, Calif., River Forecast Center - Hartford, Conn.
- (d) Theoretical and field investigation; operation and applied research.
- (e) The purpose of these investigations is the development of precipitation-runoff relations for water supply forecasting utilizing statistical methods to correlate precipitation during the winter with runoff during the melting season.
Research is being conducted on a new technique for water-supply forecasting which is based on a model which provides for a volumetric accounting of all the water in the basin.
Study is also being made of storm types as related to the ratio of high-elevation to low-elevation precipitation amounts and to determine their value for improvement of water-supply forecasts.
- (g) Water Supply Forecasts are prepared for nearly 400 points in the United States. These forecasts of water-year and residual flow are released in Monthly Water Supply Forecast Bulletins, January through May. This research program is of a continuing nature designed to improve and extend the present forecasting service.
- (h) "Development of a Digital River Basin Model," by J. F. Hanneford, and "The Little Used Third Dimension," by Eugene L. Peck, presented at Western Snow Conference, Nelson, British Columbia, April 21-23, 1964, and published in Proceedings of Conference.

(2437) UNITED STATES STORM CHARACTERISTICS.

- (b) Soil Conservation Service, Department of Agriculture.
- (d) Theoretical and field investigation; applied research and design.
- (e) Studies to provide rainfall data for design criteria in estimating required capacities of hydraulic structures. Work includes: (1) Development for the United States, Puerto Rico and the Virgin Islands of a generalized relationship between depth, area, duration and frequency for areas up to 400 square miles, durations from 2 to 10 days, and return periods from 2 to 100 years. (2) Development of a relationship between snow depth, water equivalent, and frequency of maximum water equivalent of March snow cover in north central United States. (3) Investigation of the applicability of a Markov Chain probability model to sequences of wet or dry days in climatically different regions. (4) Determination for the 48 contiguous states of mean monthly number of days having daily precipitation amounts greater than 0.49, 0.99, 1.99 and 3.99 inches. (5) Development of physiographically adjusted 6-hour rainfall-frequency maps for Arizona, New Mexico, Colorado, Utah, Nevada, Wyoming, Idaho and Montana for areas up to 400 square miles.
- (f) Items (2) and (3) completed; items (1), (4) and (5) active.
- (h) "Two- to Ten-Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous

United States," Technical Paper No. 49, U. S. Weather Bureau, 1964.
"Frequency of Maximum Water Equivalent of March Snow Cover in North Central United States," Technical Paper No. 50, U. S. Weather Bureau, 1964.
"Sequences of Wet or Dry Days Described by a Markov Chain Probability Model," by L. L. Weiss, Monthly Weather Review, Vol. 92, No. 4, pp. 169-176, April 1964.

(2438) STORM TIDE PREDICTIONS.

- (b) Laboratory projects.
- (c) Mr. D. L. Harris, Project Leader, Storm Surge Research Branch, Sea-Air Interaction Laboratory, Office of Meteorological Research, U. S. Weather Bureau, Washington, D. C. 20235.
- (d) Theoretical and field investigation; basic and applied research.
- (e) The basic research is the numerical approximation to the solutions of the hydrodynamic storm surge equations and is being done to give a better understanding of the physical processes involved in storm surge generation and modification. The applied research is the development of empirical methods of forecasting storm surges with the purpose of improving storm tide forecasts.
- (g) Empirical methods of forecasting these inundations are being developed and used in the Weather Bureau's hurricane and storm warning service. Continued improvement in these forecasts is expected to result from this research.
- (h) "A Regression Model for Storm Surge Prediction," by D. L. Harris and A. Angelo, Monthly Weather Review, Vol. 91, No. 10, 11 and 12, pp. 710-726, Oct., Nov., and Dec. 1963.
"The Relation of Wind and Pressure to Extra-Tropical Storm Surges at Atlantic City," by N. A. Pore, Journal of Applied Meteorology, Vol. 3, No. 2, pp. 155-163, April 1964.
"Some Problems Involved in the Numerical Solutions of Tidal Hydraulic Equations," by D. L. Harris and Chester P. Jelesnianski, Monthly Weather Review, Vol. 92, No. 9, pp. 409-422, Sept. 1964.

(2943) METEOROLOGICAL RADAR TRANSPONDER (MRT) FOR REPORTING RAINFALL.

- (b) Laboratory project.
- (d) Field investigation; development and operation.
- (e) A compact device, consisting of a Fischer-Porter precipitation punch-tape gage and transponder, that can be installed in relatively remote areas at an average distance of 70 miles from the radar and up to 140 miles with a mountain-top installation. Activated by a signal from the radar, the MRT transmits a pulsed signal which appears in Binary code on the radar scope indicating the accrued amounts of precipitation. Investigations are continuing for application to reporting of river and tide stage, and snow water-equivalent data.
- (g) MRT-1 is obsolete and has been taken out of service. As of July 1963 ten MRT-2's have been installed of which two are operational; the other eight being refurbished with Fischer-Porter gages. Fifteen remaining installations are to be completed.

(3251) PRECIPITATION DISTRIBUTION AS DETERMINED BY WSR-57 RADAR.

- (b) Laboratory projects at Weather Bureau Offices in Detroit, Mich., Evansville, Ind., Kansas City, Mo., Missoula, Mont., Oklahoma City, Okla., Sacramento, Calif., St. Louis, Mo., and Wichita, Kansas.
- (d) Theoretical and field investigation, operation and applied research.
- (e) Studies are being made to relate, within

- 100 N.M. of the radar, the intensity and duration of weather echoes with observed rainfall. Estimates of rainfall can be determined by use of the calibrated attenuators on the radar and converting these db values to theoretical rainfall rates by means of a rainfall rate-echo intensity graph. This use of radar applies to flood forecasting and water-supply forecasting.
- (g) Results indicate that by averaging point radar estimates of rainfall over a river basin and comparing them with observed averaged rainfall over the same basin favorable correlations within 10 percent are possible under certain weather regimes. Data collection being continued.
- (h) "Results of Precipitation Measurements with Weather Bureau Radars," by Allen F. Flanders, Proceedings of the 11th Weather Radar Conference, Boulder, Colorado, Sept. 1964.
- (3601) STUDY OF TECHNIQUES FOR MEASURING RAINFALL BY REFERENCE TO RADAR ATTENUATION.
- (b) Laboratory project in cooperation with Stanford Research Institute, Menlo Park, Calif.
- (d) Experimental; development and applied research.
- (e) By measuring the attenuation of short wave length radar signals over a fixed course and relating it to the measured precipitation along the path of the radar beam, a relationship can be established enabling an instrument to monitor areas above damsites and small headwaters for the purpose of alerting downstream interests to heavy rainfall.
- (f) Additional work temporarily suspended.
- (3602) EXTENSION OF RATING CURVES.
- (b) Laboratory project.
- (d) Field investigation; operation and applied research.
- (e) The flood forecasting procedures used by the Weather Bureau are primarily based on discharge. However, the flood warnings to be of any value must be in terms of stage (or elevation). This is accomplished by use of U. S. Geological Survey rating curves relating discharge to stage. Rating curves are defined only to the maximum observed stage of record. Therefore, it is imperative to devise a reliable method of extending rating curves in order to issue accurate stage predictions for the record breaking flood.
- (f) In abeyance, work being done by U. S. Geological Survey.
- (3920) FLOAT-TYPE RESISTANCE RIVER GAGE.
- (b) Laboratory project.
- (d) Experimental; development.
- (e) A device employing a Helipot (multi-turn potentiometer) operated by a float or connected to an existing river gage and linked by wire or radio to an observation point (up to 3 miles by wire and 50 miles by radio). A reading is obtained by balancing the resistance in the system with a similar unit at the observation point. May be operated on AC or DC power.
- (f) Completed, now operational; 120 now in use.
- (g) Field installation of units linked by land lines operational, radio link now feasible.
- (3921) PUNCHED-TAPE RECORDING, WEIGHING-TYPE PRECIPITATION GAGE WITH TELEMETERING CAPABILITY.
- (b) Laboratory project.
- (d) Experimental; development.
- (e) A twenty-inch capacity, weighing-type battery-operated precipitation gage providing a punched tape record which can be machine processed, capable of over one month's unattended operation. Gage so designated that data can be telemetered through use of a "black box" attached to recording mechanism.
- (f) Now operational, 200 installed.
- (g) Initial gages procured and undergoing laboratory and field tests. Installation and field testing began Sept. 1963.
- (4401) BINARY-DECIMAL TRANSMITTER FOR USE WITH ANALOG-DIGITAL RECORDER.
- (b) Laboratory project in cooperation with Fischer & Porter Co.
- (d) Experimental; design development.
- (e) Black-box attachment for Analog-Digital Recorder (ADR) permitting interrogation by telephone or radio of river stage data.
- (f) Completed, now operational; 100 installed, both radio and wire.
- (g) Initial installations undergoing field test.
- (4402) RADAR PRECIPITATION INTEGRATOR.
- (b) Laboratory project in cooperation with Stanford Research Institute, Menlo Park, Calif.
- (d) Experimental and field investigation, applied research and development.
- (e) A system for measuring precipitation by S-band radar, employing six levels of intensity on the log receiver, which quantizes the received radar signal from selected grid locations. The accrued precipitation is recorded on paper tape as well as displayed in units of depth by a series of electro-mechanical counters set in a map corresponding to the 140 grid locations. Because of the pulsed digital nature of the readout it is possible to transmit the signal by narrow bandwidth links. An evaluation of the system has been completed at the Weather Bureau's facility at the National Severe Storms Laboratory, Norman, Oklahoma, utilizing a dense network of recording raingages operated by the Agricultural Research Service near Norman, Oklahoma.
- (f) Additional work temporarily suspended.
- (g) The evaluation, although incomplete, shows that the basic concept has been realized and that the accuracy of the device for measurement of light rainfall has been demonstrated.
- (h) "Radar Precipitation Measurements - Phase III, Evaluation," by Ronald T. H. Collis, Final SRI Report on contract CWB-10282, January 1964.
- (4766) OCEAN-ATMOSPHERE INTERACTION.
- (b) Laboratory Project.
- (c) Dr. Kirk Bryan, General Circulation Research Laboratory, U. S. Weather Bureau, Wash. 25, D. C.
- (d) Experimental, theoretical; basic.
- (e) As part of the fundamental investigation of atmospheric processes by the General Circulation Research Laboratory, work has been initiated to study the large-scale aspects of the interaction of the ocean with the atmosphere. The problem of the response of a simplified ocean model to wind stress was chosen as a starting point. Numerical solutions for this problem incorporate a much more detailed treatment of the non-linear terms than has been possible in previous studies. Model and boundary refinements will be made to check whether the results could be explained by aspects other than the pattern of wind stress. Development of numerical models for investigating the large scale ocean circulation has continued. Solutions have been obtained for the time-dependent behavior of a six-level model of an enclosed ocean basin, in which density is a function of both temperature and salinity. Calculations have been made for several different cases corresponding to different boundary conditions at the air-sea interface. The solutions indicate that the distribution

- of evaporation minus precipitation at the ocean surface, treated only implicitly in previous studies, may have a very important effect on thermocline structure. Future work will incorporate the effect of wind stress at the surface, and the seasonal response of the model ocean to annual fluctuations in the temperature distribution and wind stress distribution at the air-sea interface.
- (h) "A Numerical Investigation of a Nonlinear Model of a Wind-Driven Ocean," by K. Bryan. Reprinted from Journal of the Atmospheric Sciences, Vol. 20, No. 6, pp. 594-606, November 1963.
- (5012) PROBABLE MAXIMUM PRECIPITATION FOR THE U. S. PACIFIC NORTHWEST (COLUMBIA RIVER DRAINAGE).
- (b) Corps of Engineers, Dept. of the Army.
(d) Applied research.
(e) Six- to 72-hour probable maximum precipitation for basins up to 1000 sq. mi. in extent, for each month. Includes temperature and winds during storm. Estimates used in design of flood control structures.
(h) Unpublished preliminary report.
- (5298) TELEMETERING PRECIPITATION GAGES.
- (b) Laboratory projects.
(d) Field Investigation; applied research and operational.
(e) Telemetering precipitation gage installations are planned around 12 of the Weather Bureau's WSR-57 radars to provide real time reporting of precipitation amounts and intensity data. These reports will be used operationally for flood forecasting and in applied research projects to calibrate rainfall as observed by WSR-57 radar. These gages are the Weather Bureau's new weighing-recording type.
(f) Equipment on order.
(g) Installation expected to start in 1965.
- (5299) ATMOSPHERIC TURBULENT TRANSFER PROCESSES OVER WATER.
- (b) Weather Bureau, in cooperation with other agencies.
(c) Dr. Donald Portman, Dept. of Meteorology and Oceanography, Univ. of Michigan, Ann Arbor, Michigan.
(d) Experimental and theoretical.
(e) To determine interrelationships of momentum, water vapor and sensible heat fluxes between the atmosphere and the water in Lake Michigan near Muskegon, Michigan, observations are taken of air temperature, humidity and wind at several heights, and of water temperature, and current velocity at several depths, and wave characteristics. These data are being analyzed by the University of Michigan. The Corps of Engineers and Public Health Service have assisted in instrumenting the project.
(g) Instrumentation completed, data being collected for analysis.
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- U. S. DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY.
- (2689) DIFFUSIONAL PROCESSES AND HYDRODYNAMICS OF SALT-FRESH WATER INTERFACE IN AQUIFERS.
- (b) Laboratory project.
(c) Mr. H. H. Cooper, Jr., U. S. Geol. Survey, Tallahassee, Fla.
(d) Field and laboratory investigation; basic and applied research.
(e) To determine the factors affecting the distribution of salt water in coastal aquifers subject to salt water encroachment.
(f) Completed.
- (2695) CONTINUOUS DISCHARGE RECORDS IN TIDAL STREAMS.
- (b) Laboratory project.
- (c) Mr. R. A. Baltzer, U. S. Geological Survey, Washington, D. C.
(d) Theoretical investigation with field applications; basic and applied research.
(e) The object is to develop mathematical model systems which are generally applicable and representative of the flow pattern and flow phenomena encountered in tidal estuaries and channels. The same basic model systems are expected to be applicable to unsteady flow conditions in nontidal reaches also.
(g) The basic partial differential equations for one-dimensional, homogeneous, unsteady flow have been derived. The method of characteristics as well as two direct finite difference methods (utilizing power series and implicit techniques, respectively) have been employed to devise evaluation methods suitable for electronic digital computer. Trial evaluation of these methods utilizing a variety of field data have indicated satisfactory results. The basic partial differential equations for both one- and two-dimensional, nonhomogeneous, unsteady flow are under analysis for the purpose of devising mathematical model systems representing estuarial reaches in which saline intrusion and diffusion occur.
(h) "Flows of Homogeneous Density in Tidal Reaches," R. A. Baltzer and John Shen, U. S. Geol. Survey open file report, Sept. 1961.
"Flows of Homogeneous Density in Tidal Reaches, by Power Series Method," R. A. Baltzer and John Shen, U. S. Geol. Survey Water Supply Paper (in review).
"Flows of Homogeneous Density in Tidal Reaches, by Method of Characteristics," Chintu Lai, U. S. Geol. Survey Water Supply Paper (in review).
"Flows of Homogeneous Density in Tidal Reaches, by Implicit Method," Chintu Lai, U. S. Geol. Survey Water Supply Paper (in review).
- (2948) ANALOG MODEL ANALYZER FOR STEADY-STATE GROUND-WATER FLOW PROBLEMS.
- (b) Laboratory project.
(c) Mr. R. W. Stallman, U.S. Geol. Surv., Denver, Colo.
(d) Theoretical study and instrument development.
(e) Use of a variable-resistance grid analyzer in analyzing steady-state ground-water flow problems in which the transmissibility varies in space.
- (2949) ULTRASONIC FLOW METER.
- (b) Laboratory project.
(c) Mr. E. G. Barron, U. S. Geological Survey, Columbus 12, Ohio.
(d) Experimental; instrument development.
(e) The objective is to measure the average velocity in a natural channel by acoustic means.
(g) Two sets of instruments have been constructed on basis of new design concepts. The instruments are being tested in the field.
- (2950) SEDIMENT TRANSPORT AND CHANNEL ROUGHNESS IN NATURAL AND ARTIFICIAL CHANNELS.
- (b) Laboratory project.
(c) Mr. Thomas Maddock, Jr., U. S. Geological Survey, Washington 25, D.C.
(d) Basic research.
(e) Field and laboratory studies, original and other investigations will be analyzed in terms of sediment movement, channel roughness, shear distribution in channel prism and other effects on shape of natural channels.
(g) Sand channel reach with controlled flow on the Rio Grande below El Paso selected for concentrated study.
- (3253) CHANNEL STABILITY IN AN EPHEMERAL STREAM.
- (b) Laboratory project.
(c) Dr. Luna B. Leopold, U. S. Geological Survey, Wash., D. C.

- (d) Field investigation, basic research.
 (e) In an ephemeral stream (arroya), measurements are being made on the following; Stress on rocks during a flow; movement and location of rocks after flow; extent of scour and fill; movement of bars; changes in cross sections at certain locations; erosion on slopes; mass movement of soils; and soil wash.
 (f) Completed.
- (3260) SOIL-MOISTURE EQUIPMENT.
- (b) Laboratory project.
 (c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U.S. Geological Survey, Denver, Colo.
 (d) Laboratory and field investigation; applied research.
 (e) Laboratory model and field comparative study of techniques and of various commercially available instruments for measuring soil moisture. New equipment may also be designed as result of study.
 (g) Field and laboratory calibrations of neutron meter, tensiometers, moisture blocks and sampling equipment. Evaluation of neutron meter. Design of small-diameter fast-response tensiometer. Library research.
 (h) "A Field Method for Measurement of Infiltration," by A. I. Johnson, U. S. Geol. Survey Water-Supply Paper 1544-F.
 "Methods of Measuring Soil Moisture in the Field," by A. I. Johnson, U. S. Geol. Survey Water-Supply Paper 1619-U (1962).
- (3263) SPECIFIC YIELD AND RELATED PROPERTIES.
- (b) Cooperative with the State of California.
 (c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U.S. Geological Survey, Denver, Colo. or Mr. Fred Kunkel, District Geologist, U. S. Geological Survey, Sacramento, Calif.
 (d) Laboratory and field investigation; basic and applied research.
 (e) Theoretical, laboratory and field study of specific yield, and related properties, such as moisture equivalent, field capacity, moisture tension, unsaturated permeability and time-drainage relationships, as related to ground-water storage. Evaluation of existing, and possible development of new methods for determining these properties.
 (g) Library research, laboratory study in progress or completed of factors affecting column drainage, centrifuge moisture equivalent, moisture tension and unsaturated permeability.
 (h) "Some Research Related to Ground-Water Recharge--A progress report from the U. S. Geol. Survey," by A. I. Johnson and Fred Kunkel: Ground-Water Recharge and Ground-Water Basin Management, Bienn. Conf., Berkeley, Calif., 1963, Proc. (1963).
 "Comparison of Drainage Data Obtained by the Centrifuge and Column Drainage Methods," by R. C. Prill: U. S. Geol. Survey Prof. Paper 424-D (1962).
 "Specific Yield and Related Properties--An Annotated Bibliography," by A. I. Johnson, D. A. Morris, and R. C. Prill: U. S. Geol. Survey open-file rept. (In preparation as U. S. Geol. Survey Water-Supply Paper 1662-F) (1961).
- (3264) SUBSURFACE EXPLORATION EQUIPMENT AND TECHNIQUES.
- (b) Laboratory project.
 (c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U. S. Geological Survey, Denver, Colo.
 (d) Laboratory and field investigation; applied research.
 (e) Evaluate and adapt subsurface sampling and coring equipment and techniques to ground-water investigations.
 (g) Core samplers designed, and some commercial models procured and compared under field conditions. Library research in progress.
 (h) "Portable Equipment for Borehole Exploration," by A. I. Johnson: U. S. Geol. Survey open-file rept. (1963).
 "Bibliography on Soil Exploration," in Symposium on Soil Exploration, by A. I. Johnson and J. P. Gnaedinger: Am. Soc. Testing Materials Spec. Tech. Pub. 351 (1964).
- (3265) INVESTIGATION OF VADOSE FLOW THROUGH POROUS MEDIA.
- (b) Laboratory project.
 (c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U. S. Geological Survey, Denver, Colo.
 (d) Experimental; basic and applied research.
 (e) Laboratory model study of infiltration of fluids from surface pits into a thick unsaturated zone above the water table.
 (g) Model tank designed and constructed; several test runs with beads of different particle size completed; library research; test runs photographed by slide and lapse-time movies.
 (h) "Model Study of Infiltration into Layered Materials," by W. N. Palmquist, Jr. and A. I. Johnson: Am. Soc. Civil Engineers Ann. Convention, Boston, Mass. (1960).
- (3939) STUDY OF RADIOACTIVE WASTES, CLINCH RIVER, TENNESSEE.
- (b) Atomic Energy Commission.
 (c) Mr. P.H. Carrigan, U. S. Geological Survey, Oak Ridge, Tennessee.
 (d) Field investigation; applied research.
 (e) Purpose is to undertake a comprehensive study of the entry, movement, location and fate of radioactive wastes discharged into the Clinch River by the Oak Ridge National Laboratory.
 (g) Laboratory flume study conducted in addition to field investigations.
- (4408) ANALOG MODELS OF HYDROLOGIC PHENOMENA.
- (b) Laboratory project.
 (c) Mr. R. A. Baltzer, U. S. Geological Survey, WRD, Washington, D. C. 20242.
 (d) Basic and applied research.
 (e) Investigation of applicability of analog computer technique to solve problems involving either hydrologic data in general or surface-water flow in particular.
 (g) Results to date indicate concept and approach are valid. Additional methods and instrumentation being investigated.
 (h) "Use of Hydrologic Models in the Analysis of Flood Runoff," John Shen, U. S. Geol. Survey Professional Paper 506-A, 1964.
 "The Role of Analog in Surface-Water Hydrological Problems," John Shen, U. S. Geol. Survey Administrative Report, Sept. 1963.
 "An Analog Solution of the Turbulent Diffusion Equation," John Shen, U. S. Geol. Survey Prof. Paper 450-E, 1963.
- (4410) BANK SEEPAGE DURING FLOOD FLOWS.
- (b) Laboratory project.
 (c) Mr. E. C. Pogge, U. S. Geological Survey, WRD, 508 Hydraulic Laboratory, Iowa City, Iowa 52241.
 (d) Field investigation; applied research for doctoral thesis.
 (e) Purpose is to understand the mechanics of seepage flow into and from bank storage along a channel in response to movement of flood waves through a channel reach.
 (g) Ground-water observation wells were located on the flood plain adjacent to stream-gaging stations at five sites. During fluctuations in stage, records of the ground-water table were obtained with time. Hydraulic properties of the bank materials were obtained and used to determine the rate and amount of bank seepage.
- (4779) LARGE-SCALE ROUGHNESS.
- (b) Laboratory project.

- (c) Messrs. J. Davidian and R. H. Walker, U. S. Geological Survey, WRD, Washington, D. C. 20242.
- (d) Field investigation; applied research.
- (e) Purpose is to study energy losses produced by large-scale roughness resulting from channel alignment and configuration.
- (g) Bed-particle samples have been collected on 64 streams in three different parts of the country. A relation between Manning's roughness coefficient, particle size, and size distribution has been found and is being refined.
- (4787) MECHANICS OF FLUID FLOW IN POROUS MEDIA.
- (b) Laboratory project.
- (c) Dr. Akio Ogata, U. S. Geological Survey, Honolulu, Hawaii.
- (d) Experimental and theoretical study; basic research.
- (e) Theoretical and laboratory study of microscopic and macroscopic aspects of flow through porous media.
- (5073) STATISTICAL DERIVATION OF THE VELOCITY PROFILE FOR TURBULENT FLOW.
- (b) Laboratory project.
- (c) Dr. N. C. Matalas and Dr. W. J. Conover, U. S. Geological Survey, WRD, Washington, D. C. 20242.
- (d) Theoretical; basic and applied research.
- (e) A statistical model of turbulence, based on a random walk process, is developed to represent two-dimensional flow. This model is used to derive a mathematical form of the velocity profile across the turbulent field.
- (f) Completed.
- (g) The velocity profile is defined as a three parameter hyperbolic function, with two parameters reflecting the effect of bed roughness and fluid viscosity on the shape of the velocity profile and the fluid parameter being the mean velocity across the turbulent fluid. This profile is shown to provide as good and in some cases a better fit to observations than the logarithmic velocity distribution.
- (h) "Derivation of the Velocity Profile From a Statistical Model of Turbulence," by N. C. Matalas and W. J. Conover (in review).
- (5074) DISPERSION IN OPEN CHANNELS.
- (b) Atomic Energy Commission.
- (c) Dr. N. Yotsukura, U. S. Geological Survey, Washington, D. C.
- (d) Theoretical and laboratory investigation; basic research.
- (e) To relate longitudinal dispersion to channel geometry, boundary roughness, and flow characteristics.
- (f) Completed.
- (g) Longitudinal dispersion is strongly influenced by velocity transport and its coefficient relative to lateral diffusion coefficient is a function of friction factor, which depends on Reynolds number and boundary roughness.
- (5075) DOPPLER VELOCITY METER.
- (b) Laboratory project.
- (c) Mr. G. F. Smoot, U. S. Geological Survey, WRD, Washington, D. C. 20242.
- (d) Experimental; instrument development.
- (e) The objective is to measure the instantaneous local velocity by means of the Doppler frequency shift of an ultrasonic signal reflected by minute particles of suspended sediment.
- (g) Model undergoing laboratory and field tests.
- (5076) DISTRIBUTION AND CONCENTRATION OF RADIO-ACTIVE WASTE IN STREAMS BY FLUVIAL SEDIMENT.
- (b) U. S. Geological Survey for Atomic Energy Commission.
- (c) Mr. William W. Sayre, Project Chief, U. S. Geological Survey, c/o Engineering Research Center, Foothills Campus, Colorado State University, Fort Collins, Colorado 80521.
- (d) Experimental and theoretical; basic and applied research.
- (e) A significant fraction of the low level liquid radioactive wastes which are discharged into surface streams is often sorbed by bed material and fine material sediment particles. Consequently the manner in which these sediments are transported is a significant factor in determining the distribution of radioactive wastes in the stream environment. The project is devoted to investigating the dispersion and transport of both fine and bed material sediment particles. Experiments are being conducted in natural streams and in laboratory flumes. Radioactive tracer techniques, fluorometry and nephelometry are among the experimental techniques being employed. Analytically and experimentally the phenomenon of sediment transport is being treated from a Lagrangian point of view.
- (g) The transport of bed material particles can be described as an alternating sequence of steps and rest periods in which the step lengths and rest period durations are exponentially distributed. In stochastic processes this would be known as a compound Poisson process. This yields a concentration distribution function which agrees with distributions of concentrations of radioactive tracer particles observed in the North Loup River, Nebraska, and in a laboratory flume. Radioactive tracer techniques provide a feasible method for determining bed material discharge averaged over a period of time. The longitudinal dispersion of dye and fine suspended sediment particles in a wide rectangular open channel with a rough boundary follows closely the prediction of the Taylor-Elder theory in which a virtual coefficient of longitudinal dispersion is computed using the velocity distribution and the Reynolds analogy concerning the equivalence of mass and momentum transfer. Also in such a channel, experiments to date indicate that at large distances from the source the rate of lateral dispersion from a continuous point source is essentially constant over most of the flow depth.
- (5077) ARTIFICIAL CONTROLS FOR ALLUVIAL CHANNEL STREAMS.
- (b) Laboratory project.
- (c) Mr. F. A. Kilpatrick, Project Chief, U. S. Geological Survey, c/o Engineering Research Center, Foothills Campus, Colorado State University, Fort Collins, Colorado 80521.
- (d) Field investigation; applied research.
- (e) The basic stream flow data collection program of the U. S. Geological Survey for sand bed channels is in need of improvement. Such channels have unstable stage-discharge relationships. Thus effort is being made to develop control designs and construction methods suitable for alluvial channels. Methods for improving the stability will be designed and then tested in the laboratory and field. Careful consideration will be given to construction techniques in order to minimize costs to the data collection program.
- (5078) ALLUVIAL CHANNEL HYDRAULICS.
- (b) U. S. Geological Survey.
- (c) Messrs. H. P. Guy, E. V. Richardson, and D. B. Simons, U. S. Geological Survey, c/o Engineering Research Center, Foothills Campus, Colorado State University, Fort Collins, Colorado 80521.
- (d) Experimental; basic research.
- (e) A laboratory study of resistance to flow, sediment transport and related problems in alluvial channels.
- (g) Five different bed materials ranging in

- size from 0.19 millimeters to 0.93 millimeters have been studied. The forms of bed roughness which occur and their relation to sediment transport and resistance to flow have been studied and described. The effect of large concentrations of suspended fine sediment (clay), the viscosity of the water and the specific weight and gradation of the bed material on the mechanics of flow and on sediment transport in alluvial channels have also been investigated.
- (h) "Bedload Equation for Ripples and Dunes", by D. B. Simons, E. V. Richardson, and C. F. Nordin, U. S. Geol. Survey Prof. Paper 462-H, 1965.
 "Resistance to Flow in Alluvial Channels", D. B. Simons, E. V. Richardson, U. S. Geol. Survey Prof. Paper 422-I, 1965.
 "Sediment Transport in Alluvial Channels", D. B. Simons, E. V. Richardson, and C. F. Nordin, Jr., U. S. Geol. Survey Prof. Paper 462-I, 1965.
 "Summary of Alluvial Channel Data from Flume Experiments," by H. P. Guy, D. B. Simons, and E. V. Richardson, U. S. Geol. Survey Prof. Paper 462-L, 1965.
 "Sedimentary Structures Generated by Flow in Alluvial Channels", by D. B. Simons, E. V. Richardson, and C. R. Nordin, Jr., a symposium, Soc. Econ. Paleontologists and Mineralogists.
 "Total Bed-Material Discharge in Alluvial Channel," by F. M. Chang, D. B. Simons, and E. V. Richardson, 1964, in preparation.
 "Total Bed-Material Transport", A. A. Bishop, D. B. Simons, and E. V. Richardson, 1964, in preparation.
- (5599) RESEARCH ON PERMEABILITY.
- (b) Cooperative with the State of California.
 (c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U. S. Geological Survey, Denver, Colo. or Mr. Fred Kunkel, District Geologist, U. S. Geological Survey, Sacramento, Calif.
 (d) Laboratory and field investigation; basic and applied research.
 (e) Theoretical, library, laboratory, and field study of permeability, mainly as related to water movement through rock and soil materials, both as saturated and unsaturated flow. Evaluation of existing laboratory and field methods and development of new or improved methods.
 (g) Library research leading to an annotated bibliography on permeability (manuscript in preparation). Laboratory study of factors affecting saturated permeability measurements in progress. Laboratory study of relation between particle-size parameters and permeability. Laboratory evaluation of unsaturated permeability methods.
 (h) "Application of Laboratory Permeability Data," by A. I. Johnson: U. S. Geol. Survey open-file rept. (1963).
 "Some Research Related to Ground-Water Recharge--A progress report from the U. S. Geol. Survey," by A. I. Johnson and Fred Kunkel: Ground-Water Recharge and Ground-Water Basin Management, Bienn. Conf., Berkeley, Calif., 1963, Proc. (1963).
- (5600) MOVING BOAT TECHNIQUE FOR MEASUREMENT OF OPEN-CHANNEL DISCHARGE.
- (b) Laboratory project.
 (c) Mr. G. F. Smoot, U. S. Geological Survey, WRD, Washington, D. C. 20242.
 (d) Experimental; instrument and technique development.
 (e) The purpose of this research is to provide the instrumentation and to develop the technique needs to rapidly, accurately and inexpensively measure flow, especially unsteady flow, in rivers and tidal estuaries.
 (g) A Doppler navigator, Doppler velocity meter, and a sonic sounder are being coupled together to provide channel discharge. The navigator provides the transverse distance traveled across the channel, the sonic sounder provides the cross-section depth, and the velocity meter provides the flow vector from which the discharge may be electronically integrated.
- (5601) FORMATION OF ICE IN STREAMS.
- (b) Laboratory project.
 (c) Mr. K. L. Carey, U. S. Geological Survey, 5001 University Avenue, Madison, Wisconsin 53705.
 (d) Field investigation; basic and applied research.
 (e) The study has as its objective the determination of the manner of ice formation in streams in order to provide more accurate, reliable, and less costly techniques for determining flow under ice.
 (g) An intensive field investigation of two selected reaches of the St. Croix and Chippewa Rivers in Wisconsin is underway. Auxiliary gaging stations are being installed together with thermal sensing and other special instrumentation to enable study of the heat budget.
- (5602) STATISTICAL DERIVATION OF OPEN-CHANNEL SEDIMENT TRANSPORT FUNCTION.
- (b) Laboratory project.
 (c) Dr. N. C. Matalas and Dr. W. J. Conover, U. S. Geological Survey, WRD, Washington, D. C. 20242.
 (d) Theoretical study; basic and applied research.
 (e) A statistical model of two-dimensional sediment transport in open channels, based on a random-walk process, is used to develop a sediment transport function.
 (g) A distribution profile of sediment transport based upon bed roughness, fluid resistance, particle fall-drag, and the mean sediment discharge is defined in terms of hyperbolic functions. The model is designed to include both bed load and suspended load.
- (5603) ORIGIN OF BASE FLOW.
- (b) Laboratory project.
 (c) Dr. G. R. Kunkle, U. S. Geological Survey, WRD, 508 Hydraulics Laboratory, Iowa City, Iowa 52241.
 (d) Field investigation; basic and applied research.
 (e) The objective of this study is to determine the origin and characteristics of low flows as related to the hydrology and geology of a small drainage basin. Specific information is sought upon those hydrologic and geologic factors having the most influence upon low flows.
 (g) The geology and soils of Four-Mile Creek basin in Tama County, Iowa have been mapped. Accurate stream inflow and outflow records are being gathered together with precipitation, soil moisture, and shallow well information.
- (5604) MECHANICS OF FLUID RESISTANCE.
- (b) Laboratory project.
 (c) Dr. H. J. Tracy, U. S. Geological Survey, WRD, Room 164 Peachtree Seventh Building, Atlanta, Georgia 30323.
 (d) Theoretical and laboratory investigation; basic research.
 (e) The objective of this study is to attempt to describe the effects of the boundary of fluid resistance in terms of dimensionless ratios characterizing the physical size and shape of the roughness. Ultimately, it is expected that a general theory of the nature of the energy-momentum transport mechanism will result.
 (g) The experimental aspect of the work is being conducted in an artificially roughened, closed circular, air tunnel using hot-wire anemometer equipment to determine velocity profiles, turbulence, and energy spectra. The work consists of tests in

- which roughness element size, density of spacing, and shape are systematically varied. The resulting turbulence spectra are being analyzed in order to correlate the physical dimensions of the roughness with the energy and momentum transfer mechanisms in turbulent flow.
- (5605) FLUID RESISTANCE AT EXPANSIONS AND CONTRACTIONS.
- (b) Laboratory.
 - (c) Dr. Nobuhiro Yotsukura, U. S. Geological Survey, WRD, Washington, D. C. 20242.
 - (d) Theoretical and experimental investigation; basic research.
 - (e) The objective of this study is to gain a more basic understanding of the actual mechanism of flow separation and associated losses.
 - (g) Although exploratory experimental work will be carried out, considerable effort is given to development of a rational analytical approach based upon drag and momentum concepts.
- (5606) MULTIPLE CHANNEL DIGITAL RECORDING SYSTEM.
- (b) Laboratory project.
 - (c) Mr. G. F. Smoot, U. S. Geological Survey, WRD, Washington, D. C. 20242.
 - (d) Instrument development.
 - (e) The objective of this project is to develop a reliable, battery powered, sensing instrument for field operation which is capable of positioning a punched paper-tape digital recorder. The instrument would be used to provide a variety of hydrologic parameters in rapid sequence for recording on tape.
 - (g) A transistorized system incorporating an A-C Wheatstone bridge balanced by a D-C servo system of minimum power requirements has been developed and is undergoing field testing.
- (5607) EVALUATION OF DEPENDENT AND INDEPENDENT VARIABLES IN OPEN CHANNEL FLOW.
- (b) U. S. Geological Survey.
 - (c) Messrs. H. P. Guy and C. F. Nordin, Jr., U. S. Geol. Survey, c/o Engineering Research Center, Foothills Campus, Colo. State Univ., Fort Collins, Colo. 80521.
 - (d) Experimental; basic research.
 - (e) The objective is to identify and evaluate the dependency characteristics of flow and sediment measures of alluvial channel flow. The experiments are designed to (1) determine mean flow parameters and channel adjustments when bed material is an independent variable; (2) determine the importance of depth as a scale parameter and as a driving force; (3) determine the time for change when an independent variable is changed; (4) determine the variance of slope, depth, velocity, sediment transport, and bed conditions in time and space.
- (5608) DISTRIBUTION AND CONCENTRATION OF RADIOACTIVE WASTE IN STREAMS BY FLUVIAL SEDIMENT.
- (b) U. S. Geological Survey.
 - (c) Messrs. W. W. Sayre and F. M. Chang.
 - (d) Experimental and theoretical; basic and applied research.
 - (e) A significant fraction of the low level liquid radioactive wastes which are discharged into surface streams is often sorbed by bed material and fine material sediment particles. Consequently the manner in which these sediments are transported is a significant factor in determining the distribution of radioactive wastes in the stream environment. The project is devoted to investigating the dispersion and transport of both fine and bed material sediment particles. Experiments are conducted in natural streams and in laboratory flumes. Radioactive tracer techniques, fluorometry and nephelometry are among the experimental techniques being employed. Analytically and experimentally the phenomenon of sediment transport is being treated from a Lagrangian point of view.
- (f) Discontinued.
- (g) The longitudinal dispersion of fine suspended sediment particles in a turbulent open-channel flow tends to be more rapid than that of dye. The degree of difference depends on the fall velocity of the particles and the flow characteristics in the channel.
- (h) "Sand Transport Studies with Radioactive Tracers," by D. W. Hubbell and W. W. Sayre, Am. Soc. Civil Engineers Proc., v. 90, no. HY3, May 1964, p. 39-68.
- "Exploratory Laboratory Study of Lateral Turbulent Diffusion at the Surface of an Alluvial Channel," by W. W. Sayre and A. R. Chamberlain, U. S. Geol. Survey Circ. 484, 1964.
- (5609) STEP LENGTHS AND REST PERIODS OF SEDIMENT PARTICLES IN ALLUVIAL CHANNELS.
- (b) U. S. Geological Survey.
 - (c) Messrs. W. W. Sayre and F. M. Chang.
 - (d) Experimental and theoretical; basic research.
 - (e) The object is to study the individual and collective motions of bed-material sediment with a view to obtaining better understanding of the fundamental transport processes. Radioactive tracer and other techniques will be used to determine (1) distribution functions for the step lengths and rest periods of sediment particles and (2) how the parameters describing the distribution functions are related to sediment and flow characteristics.
- (5610) MECHANICS OF FLOW STRUCTURE AND FLUID RESISTANCE--MOVABLE BOUNDARY.
- (b) U. S. Geological Survey.
 - (c) Mr. E. V. Richardson.
 - (d) Experimental, theoretical and field investigation; basic research.
 - (e) The objective is to measure the internal flow field of turbulent shear flow in an open channel in order to obtain a fundamental understanding of the mechanics of fluid resistance. Further knowledge of the mechanics of flow structure will give a better understanding of the phenomena of energy dissipation, velocity distribution, shear distribution and the transport and dispersion of solutes and sediment.
- (5611) FALL VELOCITY OF GRAVEL-SIZED PARTICLES.
- (b) U. S. Geological Survey.
 - (c) Messrs. H. P. Guy and G. L. Stringham.
 - (d) Experimental and theoretical; basic and applied research.
 - (e) The objective is to evaluate the effects of size, shape, density, and fluid characteristic on the fall velocity of gravel-sized sediment particles and to make exploratory studies on the physical significance of the Reynolds number and the effect of turbulence on fall velocity.
 - (g) A new parameter to modify the Cory Shape Factor involving the surface area of the particle has been developed for correlation with fall velocity.
 - (h) "Terminal Fall Velocity of Particles of Irregular Shapes as Affected by Surface Area," by G. R. Alger, Ph.D. dissertation, Colorado State Univ., Fort Collins, Colorado, 1964.
- (5612) STATISTICAL ANALYSIS OF RIPPLES, DUNES AND ANTIDUNES.
- (b) U. S. Geological Survey.
 - (c) Messrs. C. F. Nordin and J. H. Algert.
 - (d) Experimental; basic and applied research.
 - (e) The objective is to statistically analyze the frequency distribution of length, amplitude, and shape of bed forms and their sequential dependence on parameters of flow and sediment transport. Data are obtained from sonic

records of the movement of these forms under conditions of equilibrium flow in laboratory flumes.

U. S. DEPARTMENT OF THE INTERIOR, BUREAU OF MINES,
Morgantown Research Center.

(4436) FLOW PROPERTIES OF COAL-WATER SLURRIES.

- (b) Laboratory project--information for general public use.
- (c) Mr. J. P. McGee, Research Director, Morgantown Research Center, Morgantown, West Virginia.
- (d) Experimental; applied research.
- (e) The object of the project is to establish friction factor-Reynolds number relationships for coal-water slurries of various concentrations with coals of different ranks and size analyses. Work is being done with 1/2 inch, 3/4 inch, and 1 inch pipes. Data are processed on an IBM-1620 computer.
- (g) Preliminary results show a change in rheological classification at or above 45 percent coal concentrations.

(4790) DIELECTRIC SEPARATION OF PARTICLES FROM SUSPENSIONS OF FINE COAL IN OIL.

- (b) Laboratory project.
- (c) Mr. J. P. McGee, Research Director, Morgantown, Research Center, Morgantown, W. Va.
- (d) Experimental; applied research for a M.S. thesis at West Virginia University.
- (e) The purpose of the project is to explore the feasibility of separating solid particles in nonpolar liquids by the application on a nonuniform electric field to a flowing stream of the suspension and in particular the separation in an oil vehicle of fine coal from its ash constituents.
- (g) Capacitance cells have been constructed for determining the dielectric constants of the solids fractions and the oils in the suspensions.

U. S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION.

Inquiries concerning the following projects, except where otherwise indicated, should be addressed to Office of Chief Engineer, Bureau of Reclamation, Denver Federal Center, Denver, Colo. 80225.

(2719) GLEN CANYON DAM SPILLWAY.

- (b) Laboratory project.
- (d) Experimental; design.
- (e) The model, built to a scale of 1:63.5, included the tunnel spillways on both sides of the river, the curved arch dam, the outlet works, the powerhouse and a section of the Colorado River upstream and downstream from the dam. The tunnel spillways were modeled in transparent plastic so that flow conditions could be thoroughly investigated. Other features studied were the approach channels to the spillway, the discharge capacity of the spillways, the pressures throughout the spillways, the flip buckets and scour at the downstream portal of the tunnels, and the effect in the river when all structures are discharging.
- (f) Completed.
- (g) Alignments for the excavated spillway approach channels, tunnel transitions between the spillway crest and the inclined tunnel, new type flip buckets in new locations, and other recommended features and procedures have resulted from the studies.
- (h) "Hydraulic Model Studies of the Spillways and Outlet Works--Glen Canyon Dam," by T. J. Rhone, Hydraulics Branch Report No. Hyd-469, Feb. 1964.

(2959) STILLING BASINS FOR SLIDE GATE CONTROLLED

OUTLET WORKS.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A model was constructed to generalize stilling basin dimensions, using either one or two slide gates.
- (g) Data were taken for two types of stilling basins for high-head slide gates. Preliminary design curves were developed for the usual hydraulic jump basin and for a simple plunge-type basin.
- (h) Progress report in preparation.

(2960) FLAMING GORGE DAM SPILLWAY.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:36 scale model was used to develop a satisfactory spillway and outlet works.
- (f) Completed.
- (g) A satisfactory approach channel was developed, and good flow conditions through the crest section, transition, and throughout the spillway tunnel were obtained by the use of an unusual center pier. A new type of flip bucket was developed which permitted the height of one sidewall to be reduced without causing adverse flow conditions. The extent of riprap protection in the powerplant afterbay necessary during diversion through the outlet works was also determined.
- (h) "Hydraulic Model Studies of Flaming Gorge Dam Spillway and Outlet Works," by T. J. Rhone, Hydraulics Branch Report No. Hyd-531, May 1964.

(3267) CANAL INLET AND OUTLET TRANSITION STUDIES.

- (b) Laboratory Project.
- (d) Experimental; for design.
- (e) An existing model will be modified and used to check inlet transition data previously obtained and reported. The model will be of larger scale than the one previously used, and will show if scale effects are present, and will increase reliability of the results.
- (h) "Hydraulic Design of Transitions for Small Canals," by W. P. Simons, Engineering Monograph No. 33, United States Department of the Interior, April 1964. Available through Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

(3274) CONSTANT HEAD ORIFICE TURNOUT.

- (b) Laboratory project.
- (d) Experimental; applied research for design.
- (e) A 24-inch slide gate turnout is being calibrated by means of a 1:2 scale model. Design changes resulting from use of the turnout have necessitated an analysis and calibration of the variables affecting the discharge capacity.
- (f) Completed.
- (g) Results show that submergence of the orifice or of the upstream gate of the two-gate turnout has a major effect on the discharge coefficient. A calibration curve for a 9 cfs standard turnout and several comparative calibrations of modified turnouts have been obtained.
- (h) Report in preparation.

(3278) CAVITATION OF CONCRETE SURFACE IRREGULARITIES.

- (b) Laboratory project.
- (d) Experimental; applied research and design.
- (e) Into-the-flow offsets with abrupt edges, chamfered edges, and rounded edges were tested to determine the velocity-head relationships for incipient cavitation.
- (g) Data analysis not completed.
- (h) Progress report to be prepared.

(3611) ADJUSTABLE WEIR.

- (b) Laboratory project.
- (d) Combined laboratory and field research.

- (e) Weirs having adjustable crest height are used for checking water surface levels for upstream water delivery and for water measurement beyond the weir. An investigation of the head discharge capacity of a single 2-foot crest-length weir was completed.
 - (f) Single weir investigation completed.
 - (g) Capacities of weir for crest heights greater than 0.1 foot above fixed blade compare very favorably with standard 2-foot cipolletti weir.
 - (h) Report in preparation.
- (3612) DISCHARGE COEFFICIENTS FOR RADIAL GATES.
- (b) Laboratory project.
 - (d) Experimental, laboratory and field investigations; applied research.
 - (e) Radial gates are used extensively in irrigation systems for discharge and water surface level control. Intelligent operation of the systems requires that the rate of flow passing the gated structure be known. Literature research resulted in an analytical approach and adjusted equation for the gate capacity with unsubmerged flow.
 - (g) Extensive model and prototype radial gate data were obtained from the TVA Hydraulic Laboratory. The data are being analyzed to verify the proposed discharge formula and to extend the scope of presently available information.
- (3614) EXPERIMENTAL STUDY OF SUBCRITICAL FLOW IN CURVED CHANNELS.
- (b) Laboratory project.
 - (d) Experimental; applied research and design.
 - (e) A fixed-bed, hydraulic model has been constructed to determine the possibility of reduction in scour and deposition in unlined channels due to secondary currents. A Preston Tube has been constructed and is being used to measure boundary shear along the curved portion of the trapezoidal model channel.
 - (f) Tests in progress.
 - (g) For a given model discharge of 2.85 cfs at a depth of 0.75 feet high boundary shear stresses existed on the outside bank downstream from the curve and to a lesser extent on the inside bank in the leading portion of the curve.
 - (h) "Progress Report No. I-Boundary Shear Distribution Around a Curve in a Model Canal," by E. R. Zeigler, Hydraulics Branch Report No. Hyd-526, June 1964.
- (3985) DISCHARGE CAPACITY OF LARGE CONCRETE-LINED CANALS.
- (b) Laboratory project.
 - (d) Experimental, laboratory and field investigations; applied research and design.
 - (e) This study is for the purpose of exploring the effects on the hydraulic gradient of the relationship of boundary surface resistance to the cumulative resistance of crossings, inlets, turnouts, checks, and other local items in concrete-lined canals of different sizes, shapes, and grades. This study is part of a program to explain why design procedures used successfully for small and medium sizes of canals may not be adequate for large concrete-lined canals on flat slopes.
 - (g) Between 1957 and 1962, tests were made on 170 miles of nine large (700 to 13,200 cfs) canals having ages ranging from 7 to 25 years. Resistance coefficients varied with the amount growth, canal alignment, and canal size and ranged from 0.013 to 0.016 for the smaller canals, and from 0.015 to 0.019 for the larger canals.
- (3989) YELLOWTAIL DAM SPILLWAY.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A 1:50 scale model was used to study the spillway intake, the tunnel, and the hydraulic jump stilling basin. The basin was designed to still flows up to 12,000 second-feet and to flip larger flows up to 92,000 second-feet into the river channel.
- (f) Completed.
- (g) The following were developed during the study; width and allinement of the approach channel, length and shape of the pier at the gate section, discharge calibrations, curvature of the tunnel trajectory approaching the combination flip bucket stilling basin, length, depth and shape of the flip bucket basin, and riprap requirements downstream from the basin.
- (h) "Hydraulic Model Studies of Yellowtail Dam Spillway," by G. L. Beichley, Hydraulics Branch Report No. Hyd-483, August 1964.
- (3994) HYDRAULIC JUMP CHUTE BLOCK AND BAFFLE BLOCK PRESSURES.
- (b) Laboratory project.
 - (d) Experimental; applied research.
 - (e) A spillway stilling basin model has been constructed to study chute block and baffle block pressures and to relate these pressures to the Froude number of the entrance flow and to tailwater depth.
- (3996) HIGH HEAD ORIFICE STUDIES.
- (b) Laboratory project.
 - (d) Experimental; applied research and design.
 - (e) Tests were made at heads up to 500 feet with circular concentric orifices and a gate valve in a 3-inch-diameter pipeline to determine cavitation characteristics and effects of cavitation on head loss, discharge coefficients, pressure distribution, velocity distribution, and pressure fluctuations.
 - (f) Inactive.
 - (g) The results showed that head losses across orifice stations were not significantly changed by cavitation, discharge coefficients were affected if the coefficients were based on pressures measured downstream from the orifice, and almost normal pressure and velocity distribution reoccurred within five pipe diameters downstream from the orifice or valve station. Easily used cavitation index valves were established for a range of orifice sizes to determine when cavitation would begin, and the pressure and velocity conditions needed to prevent it.
 - (h) "Progress Report on Hydraulic Characteristics of Pipeline Orifices and Sudden Enlargements Used for Energy Dissipation," by J. W. Ball and W. P. Simmons, Hydraulics Branch Report No. Hyd-519, December 1963.
- (4416) BLUE MESA DAM SPILLWAY.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A 1:32.78 scale model was used to study the radial gate controlled intake, inclined tunnel, and the flip bucket for flows up to 33,650 cfs discharging at a velocity of 113 feet per second at the outlet portal.
 - (f) Tests completed.
 - (g) The approach channel shape, tunnel transition section at the intake, inclined tunnel, vertical bend in tunnel, and flip bucket were developed.
 - (h) "Hydraulic Model Studies of Blue Mesa Dam Spillway," by G. L. Beichley, Hydraulics Branch Report No. Hyd-515, July 1964.
- (4425) WATER-COLUMN SEPARATION.
- (b) Division of Design Project.
 - (d) Theoretical and field investigation; applied research.
 - (e) Field tests are being used to check theoretical developments designed to predict completely the hydraulic transient conditions occurring during separation and rejoining of water columns occurring during separation and rejoining of water columns in pump discharge lines.

- (f) Continuing.
 - (g) Results of field measurements of transients in two pump discharge lines show that these pressures were greater than had been predicted during design. A theory and method of analysis were developed which explain the time-history of the transients measured.
 - (h) "Water-Column Separation at Two Pumping Plants," by R. V. Brown, Applied Mathematics and Mechanics Section, Technical Engineering Analysis Branch, May 1964.
- (4791) HIGH-VELOCITY JET ON PROTECTIVE COATINGS.
- (b) Laboratory project.
 - (d) Experimental; for operation and maintenance.
 - (e) A 100-fps, 1-inch-diameter jet was impinged at 45 degrees on protective coverings proposed for application on concrete surfaces to be subjected to high-velocity flow.
 - (f) Completed.
 - (g) All protective coatings tested, in which the surface was unbroken, withstood the jet for 4 hours. All coatings tested in which a broken or cut surface extended to the concrete were ripped from the concrete test blocks in less than 5 minutes.
 - (h) Report in preparation.
- (4792) CANADIAN RIVER AQUEDUCT CHECK TOWERS.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) Laboratory tests are being made to determine the hydraulic losses and air-entrainment potential of check towers to be installed in the 125-mile-long Canadian River Aqueduct. The aqueduct consists of 54-, 60-, and 66-inch-diameter concrete conduit. The check towers are so designed that the top of each is slightly below the hydraulic grade line when the aqueduct is flowing full. Each check tower consists of a 90 degree vertical bend to direct the conduit upward, a 180-degree return bend at the top of the tower, and a 90-degree bend at the bottom of the downstream leg to return the conduit to the original alignment. There is a 22-inch air vent at the top of each tower.
 - (f) Completed.
 - (g) Head loss was determined for each size check tower. During filling or evacuating the tower, air was entrained in the downstream leg and carried into the horizontal conduit. A 36-inch-diameter vent was installed 120 feet downstream from each tower to release the entrained air.
 - (h) Report in preparation.
- (4794) VERTICAL STILLING WELL.
- (b) Laboratory project.
 - (d) Applied research.
 - (e) The purpose is to obtain the optimum size, depth, and internal configuration of vertical stilling wells for high-head discharges. The test installation has a 4-foot by 4-foot-square well 6 feet deep, followed by a canal with a 4-foot bottom width and 1-1/2:1 side slopes. An adjustable downspout is symmetrically located in the well and discharges against the flat floor. Piezometers are located in the floor and lower sidewalls of the well. Adjustable corner fillets provide a means for determining optimum fillet angle, size, and height.
 - (f) Continuing.
 - (g) The addition of corner fillets to the well results in much smoother water surfaces. The fillets direct the flow from the corners back to the center of the well inducing roller action. Optimum fillet configuration has been determined for one ratio of downspout area to well area. Additional studies will determine optimum fillet configurations for larger downspouts.
- (4799) SAN LUIS DAM SPILLWAY.
- (b) Laboratory project.
- (d) Experimental; for design.
 - (e) A 1:14.83 scale model was used to study the morning-glory spillway intake, vertical shaft, and vertical bend for flows up to 3,000 cfs, dropping approximately 100 feet through the inlet and vertical shaft.
 - (f) Tests completed.
 - (g) A deflector, with air vent and guide vanes, was developed for the vertical bend.
 - (h) "Hydraulic Model Studies of San Luis Dam Spillway," by G. L. Beichley, Hydraulics Branch Report No. Hyd-516, Sept. 1964.
- (4800) SAN LUIS DAM FOREBAY SPILLWAY.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A 1:22 scale model was used to study the morning-glory inlet, vertical bend, and stilling basin for flows up to 3,600 flowing at approximately 50 feet per second at the tunnel exit portal.
 - (f) Completed.
 - (g) Morning-glory-inlet, tunnel, and stilling basin size requirements were determined. A deflector, air vent, and guide vanes were developed for the vertical bend. Pressures in the inlet, vertical bend, and stilling basin were recorded.
 - (h) "Hydraulic Model Studies of San Luis Forebay Dam Spillway," by G. L. Beichley, Hydraulics Branch Report No. Hyd-517, November 1964.
- (4802) STUDIES ON ORIFICES FOR AUTOMATIC RADIAL GATE CONTROLS.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) The studies are for the purpose of determining flow characteristics and discharge coefficients for various size orifices in floatwell intakes of automatic radial gate controls. Studies to date have been made of 1-inch and 3-inch orifices in horizontal and vertical planes, in nonstandard settings with different approach and exit conditions for heads from 1 to 100 feet. Presently a 1:1 scale model of a floatwell intake structure is being constructed to determine discharge coefficients of the irregular orifice configuration in the regulating structure.
 - (g) Although the test arrangements differed substantially from arrangements for which data are presently available, measured coefficients compared closely with existing data.
- (4807) MORROW POINT DAM SPILLWAY AND OUTLET WORKS.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A 1:24 scale model was constructed to aid in the development of the unusual design of the spillway and outlet works for the thin-arch concrete dam. The original design, consisting of a free overfall spillway and an outlet works located near the bottom of the dam, was abandoned because of undesirable flow conditions in the artificially formed stilling pool at the base of the dam. The present design includes four fixed-wheel gate controlled conduits near the top of the dam which discharge 34,400 cfs, allowing it to fall approximately 400 feet to the stilling pool. The small slide-gate-controlled outlet works in the lower portion of the dam and the underground powerplant tailrace channels are also included.
 - (f) Completed.
 - (g) Model studies have proven the acceptability of the present design. Design of the control weir which forms the stilling pool was modified and the two inside spillway conduits were tipped downward to provide more even distribution of impact of the free-falling jets. Revisions were made to the topography of the downstream river channels to improve flow conditions

- in those areas.
- (h) Report in preparation.
- (4808) JOES VALLEY DAM SPILLWAY.
- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:20 scale model was used to study hydraulic features of the morning-glory spillway. The model included the spillway entrance, a portion of the reservoir topography surrounding the entrance, the vertical bends, and a portion of the horizontal tunnel.
- (f) Completed.
- (g) Minor modifications were made to the preliminary design to correct undesirable flow conditions which prevailed for the maximum discharge of 5,000 second-feet. Appurtenant devices were developed to control the vortex which formed during submerged operation and improve flow conditions during unsubmerged operation.
- (h) "Hydraulic Model Studies of Joes Valley Dam Spillway," by D. L. King, Hydraulics Branch Report No. Hyd-528, August 1964.
- (4947) OROVILLE DAM INCLINED POWERPLANT INTAKE TOWERS.
- (b) California Department of Water Resources.
- (c) California Dept. of Water Resources, Sacramento 2, Calif.
- (d) Experimental; for design.
- (e) Hydraulic phenomena of the unique inclined intake towers were studied in a 1:24 scale model. Temperature control shutters were arranged on the towers so water could be drawn from selected levels in the reservoir to maintain desired river temperatures for irrigation and for fish propagation. Differential pressures across these very large gates, and any tendencies for hydraulic instability during operation were studied.
- (f) Completed.
- (g) (1) The uppermost temperature control shutters must be a minimum of 40 feet below the reservoir water surface to prevent air entrainment by vortices. (2) The head loss is 2.9 feet for maximum discharge (8,600 cfs) with water flowing through the trashracks, past the temperature control shutters and emergency closure gate, and into the 22-foot-diameter penstock. (3) A head differential of 3 feet will exist across the 40- by 42-foot temperature control shutters during normal power plant operation.
- (h) Report in preparation.
- (4948) OROVILLE DAM SPILLWAY.
- (b) California Department of Water Resources.
- (c) California Department of Water Resources, Sacramento 2, Calif.
- (d) Experimental; for design.
- (e) Models built to 1:48 and 1:78 scale are being used to study the hydraulic features of a revised design of the flood control outlet. The general flow conditions, discharge coefficients, water surface profiles, flow velocities and energy dissipation as the flow reaches the Feather River are being tested on the 1:78 scale model of the entire outlet structure. The 1:48 scale sectional model of four of the eight outlet bays is being used to obtain discharge capacities for controlled and uncontrolled releases. Pressures along the pier walls and bellmouth roof of the bays were recorded from this model. A 1,740-foot-long uncontrolled overfall spillway which will operate only during extreme flood conditions was not modeled.
- (g) Flow through the outlet approach area, bays and channel was good except for slight vortex action at the outlet entrances. Modifications at the left abutment virtually eliminated the vortices. Pressures on the pier sides and bellmouth roof were all at or slightly below atmospheric. The discharge capacity was slightly higher than design capacity. The study is being continued to obtain more efficient energy dissipation where the channel flow enters the Feather River.
- (4949) HYDRAULIC DOWNPULL COMPUTATIONS FOR GLENDON DAM FIXED WHEEL GATE.
- (b) Laboratory project.
- (d) Theoretical computations.
- (e) Computations were made to determine the effect of rapid closure of the fixed wheel gate under emergency conditions, with water standing in the gate well due to initial back pressure.
- (f) Completed.
- (g) Water temporarily trapped in the gate well creates an additional head, and hence additional hydraulic downpull, for most of the gate travel when the gate is closed rapidly. However, the peak hydraulic downpull occurs at small gate openings and is not affected by reasonably rapid gate closure.
- (h) "Hydraulic Downpull Computations for Glendon Dam Fixed Wheel Gate," by D. Colgate, Hydraulics Branch Report No. Hyd-524, April 1964.
- (4950) NAVAJO MAIN CANAL HEADWORKS.
- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:16 scale model containing two 9- by 12-foot top seal radial gates, a divided underground stilling basin, and a horseshoe-shaped downstream tunnel was constructed to aid in evaluating and improving the stilling basin performance, and to test the unusual application of radial gates. Discharges ranged up to 1,800 cfs, and heads ranged from 15 to 126.5 feet.
- (f) Completed.
- (g) A basin was developed that provided good energy dissipation and smooth water surface conditions in the downstream tunnel. Backflow, which struck the downstream faces of the radial gates for a wide range of heads and discharges, was prevented by placing curtain walls above the 15° chutes just above the path of the high velocity jets. An underpass wave suppressor in the downstream portion of the basin prevented large waves from entering the tunnel.
- (h) Report in preparation.
- (4951) SAN LUIS OUTLET WORKS EMERGENCY GATES--DOWNPULL STUDIES.
- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:35 scale model of a single intake structure and gate was constructed to study downpull characteristics. The studies were performed under controlled discharge conditions simulating maximum power generation at the powerplant, and under conditions simulating a rupture at the structure or in the downstream tunnel. Presently details are being worked out for suspending the gate on water bearings so that downpull data may be obtained by the weighing method. An attempt will then be made to correlate downpull obtained by the pressure area and weighing methods.
- (f) Phase one completed.
- (g) Uplift forces great enough to prevent closure of the gate under its own weight were eliminated by proper shaping of off-sets and recesses in the face of the gate shaft. A gate lip extension-to-leaf thickness ratio of 0.55 was selected as the optimum compromise between structural and hydraulic considerations. A maximum downpull of about 710,000 pounds will occur during emergency closure of the San Luis gate under free discharge conditions at the downstream gate frame.
- (h) Progress Report No. 1--"Research Studies on Hydraulic Downpull Forces on Large Gates"

with Special Application to the San Luis Outlet Works Emergency Gates," by R. I. Murray and W. P. Simmons, Hydraulics Branch Report No. Hyd-530, March 31, 1964.

(4952) SURGE STUDIES IN LONG, LOW-HEAD PIPELINE SYSTEMS.

- (b) Laboratory project.
- (d) Experimental; applied research and design.
- (e) Laboratory studies will be made to verify an electronic computer program for analyzing low frequency surge characteristics of long pipeline systems. The test facility consists of 1,400 feet of 4-inch pipe, a constant head water supply, a constant head terminal reservoir, and a slow closing and opening valve for producing controlled changes in rate of flow. The pipeline is interrupted at 160-foot intervals with open check stands that divide the line into individual reaches with pressure heads not greater than 2.8 feet. Total drop of the line is 24 feet.
- (f) Continuing.
- (g) A series of test runs with varying control valve closure times have been made. The results, listing head versus discharge for various stations and time intervals have been furnished for debugging and modifying an ADP program which will be used to predict prototype results.

(4953) ARBUCKLE DAM OUTLET WORKS.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) Laboratory studies were conducted on a 1:18 scale model to determine the hydraulic operating characteristics of the slide gate controlled outlet works and the effects of operation of the hydraulic jump stilling basin on an adjacent spillway stilling basin.
- (f) Completed.
- (g) All features of the design were found to be acceptable. Some fine material was deposited in the spillway stilling basin during operation of the outlet works alone but no severe eddy currents were observed in the downstream channel.
- (h) "Hydraulic Model Studies of Arbutle Dam Outlet Works," by D. L. King, Hydraulics Branch Report No. Hyd-528, August 1964.

(4954) SAN LUIS FOREBAY PUMPING PLANT INTAKE TRANSITIONS.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:15 scale model was used to compare head loss, velocity distribution, and flow patterns in various configurations of canal transitions to pumping plant intakes.
- (f) Completed.
- (g) On the basis of velocity distribution and surface flow patterns in the transition and pump intake bays a symmetrical transition was found to be more desirable than an angled transition. Head losses were too small to justify comparison on this basis. The angled transition was chosen for the final design after consideration of economic factors. Numerical methods and a digital computer were used to analyze the large volume of velocity data.
- (h) Report in preparation.

(4955) SAN LUIS FOREBAY CANAL SURGE STUDIES.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:48 scale model is being constructed to determine the magnitude and velocity of surge in a pumping plant supply canal after power failure and rejection of flow. Effects of bifurcations, curves, and canal structures and methods of relieving the surge were investigated.
- (f) Completed.
- (g) Comprehensive data were obtained on the

size, form, and velocity of surge waves following rejection of the canal flow and drainage from the pump discharge lines. A longitudinal side weir was developed to attenuate the surge to an allowable height.

(h) Report in preparation.

(4956) YELLOWTAIL AFTERBAY DAM SLUICeway AND OVERFALL WEIR.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) One to twenty-four scale models were used to determine the hydraulic operating characteristics of the afterbay dam sluiceway and overfall weir, and to develop satisfactory stilling basins for both structures. The basins were judged on appearance of flow conditions and downstream bed erosion.
- (f) Completed.
- (g) The model study resulted in hydraulic jump type stilling basins containing chute blocks, baffle piers, and an end sill (Type III) being recommended for the sluiceway and overfall weir. Both recommended structures provided smooth approach-, chute-, stilling basin-, and downstream channel-flow, and produced no erosion or movement of downstream riverbed or riprap. Discharge capacity and coefficient curves were prepared for both structures.
- (h) Report in preparation.

(4957) BAFFLED PIPE OUTLET ENERGY DISSIPATORS.

- (b) Laboratory project.
- (d) Applied research.
- (e) Hydraulic model studies are being made to extend present information concerning this type of impact energy dissipator. Prototype data from existing operating structures will be compared with model data. Investigation of erosion around the structures and in the downstream bed will be studied.

(4958) AIR DEMAND TESTS ON 84-INCH JET FLOW GATE--TRINITY DAM, CALIFORNIA.

- (b) Laboratory project.
- (d) Field investigations.
- (e) Field measurements were obtained to compare model and prototype air demand for the complete range of gate openings at maximum operating head (369 feet) on the gate. A laboratory model study was made to obtain centerline velocity coefficients for the prototype air duct to provide for quantitative analysis of field measurements.
- (f) Completed.
- (g) Maximum velocity in the air supply conduit was within design limits.
- (h) Report in preparation.

(4959) FLAT BOTTOMED TRAPEZOIDAL VENTURI FLUMES.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A pilot study of a single flume is being conducted to determine the best approach to a comprehensive program to generalize the design and calibration of this type of water measuring device.
- (g) The model study has demonstrated that the particular pilot flume tested is an adequate measuring device.
- (h) Report in preparation.

(4960) PROTOTYPE PIEZOMETRIC AND AIR DEMAND MEASUREMENTS OF 4- BY 4-FOOT TANDEM GATE--NAVAJO DAM, NEW MEXICO.

- (b) Laboratory project.
- (d) Field investigation.
- (e) To compare the model and prototype, piezometric measurements were obtained for the complete range of gate openings with a head of 164.5 feet. Prototype air demand measurements

- were made simultaneously with piezometric valves to evaluate adequacy of the air supply system. Further tests are planned at heads of about 230 feet and 300 feet to more fully evaluate the hydraulic characteristics of this gate and to check the model scaling.
- (4961) USE OF RADIOISOTOPES FOR WATER MEASUREMENT.
- (b) Laboratory project.
 - (d) Field and laboratory investigations of theoretical and experimental nature.
 - (e) The purpose of the program is to determine the applicability of the use of radioactive isotopes to measurement of open channel flows by the dilution or total count methods. The program is being continued to provide statistical data on the capabilities of the methods.
 - (g) Method produces widely varying results dependant on the quality of the radioisotope-channel water mixture, accuracy of measurement of radiostope quality, and counting sensitivity. With adequate mixing, discharge measurement accuracy of 97 percent or better appears possible.
 - (h) "Canal Discharge Measurements with Radioisotopes," a technical paper, by J. C. Schuster, presented at the Hydraulics Div. Conference of the American Society of Civil Engineers, Vicksburg, Mississippi, Aug. 18-21, 1964.
- (4962) LABORATORY INVESTIGATION OF THE REMOVAL OF SALT WATER FROM A TWO-PART AQUIFER USING TILE DRAINS INSTALLED IN THE UPPER MEMBER, AND PUMP WELLS INSTALLED IN THE LOWER AQUIFER.
- (b) Laboratory project.
 - (d) Applied research.
 - (e) Tests were performed on a 16-foot-long 1:40 scale model containing two-part and single-part aquifers to determine the hydraulic action of simulated tile ground-water drains placed 0.2 foot below the model surface. The lower aquifer was composed of coarse sand 50 times more permeable than the fine sand in the upper aquifer. For initial conditions the model was charged with salt water, concentration 6,000 ppm Na Cl, dyed blue for visual identification. Tests are continuing using vertical pump wells in the lower aquifer as drains.
 - (g) For the given prototype conditions, tile ground-water drains will not intercept and discharge fresh water if the lower aquifer contains salt water. The fresh water tends to drive the salt water ahead of it to the drain.
 - (h) Progress Report No. 2 in preparation.
- (5329) INVESTIGATION OF A SEEPAGE METER DESIGNED BY THE AGRICULTURAL RESEARCH SERVICE.
- (b) Laboratory project.
 - (d) Laboratory and field investigation; experimental.
 - (e) The purpose of the study is to investigate the accuracy and dependability of the meter which uses a variable-head technique for seepage measurement.
 - (g) Laboratory and simulated field measurements produced apparently satisfactory results, but more data is required before meter accuracy and dependability can be stated.
 - (h) "Progress Report-Investigations of a Seepage Meter Designed by the Agricultural Research Service-Lower Cost Canal Program," by C. E. Brockway, Hydraulics Branch Report No. Hyd-529, June 1964.
- (5330) FRICTION LOSSES IN LARGE TUNNELS AND PIPES.
- (b) Field project.
 - (d) Field investigation; design.
 - (e) The purpose is to provide design information on surface resistance coefficients for various sizes of pressure conduits. Piezometers for head loss measurements are installed during construction of the conduit
- (g) or at the time of the measurements. Resistance coefficients were measured on 36-, 42-, and 48-inch-diameter cast-in-place concrete pipe and on an 18-foot-diameter concrete tunnel with satisfactory results.
 - (h) "Flow Resistance Coefficients of Three Sizes of Cast-In-Place Concrete Pipe," by C. E. Brockway, Hydraulics Branch Report No. Hyd-533, August 1964.
- (5331) INVESTIGATION OF THE EFFECT OF TURNOUT GEOMETRY ON THE ACCURACY OF A PROPELLER-TYPE OPEN FLOW METER.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) The purpose of the investigation was to determine whether a change in the design of outlet structures for open flow meters from a relatively unconfined outlet to a confined outlet changed the registration accuracy of the meter.
 - (f) Completed.
 - (g) Results indicate that a confinement just large enough to pass the design discharge of the turnout did not significantly change the meter registration accuracy.
 - (h) Report in preparation.
- (5332) OROVILLE DAM POWERPLANT INTAKE GATE DOWNPULL.
- (b) California Department of Water Resources.
 - (c) California Department of Water Resources, Sacramento 2, Calif.
 - (d) Experimental; for design.
 - (e) A 1:24 scale hydraulic model was used to determine downpull forces that would occur on the 21- by 34-foot powerplant intake coaster gates during emergency closures under full powerplant operation. The pressure area method of determining downpull was used.
 - (f) Completed.
 - (g) A maximum downpull force of about 376,000 pounds will occur. No uplift was encountered. A method of computing turbine discharge with the wicket gates moving to full open as the head is reduced during closure of the intake gates is presented. Dimensionless downpull and discharge coefficients are also included.
 - (h) "Hydraulic Model Studies of the Hydraulic Downpull Forces on the Oroville Intake Gates," by K. G. Bucher, Hydraulics Branch Report No. Hyd-540, Sept. 1964.
- (5333) FLOW-INDUCED VIBRATIONS IN USBR STRUCTURE.
- (b) Laboratory project.
 - (d) Experimental and field investigations; for design.
 - (e) A compilation and discussion of a variety of vibration problems induced in Bureau structures by flowing fluids was made. Vibration problems encountered in radial gates, turbine runners, turbine draft tubes, pump discharge lines, pipeline distribution systems, and overfalling nappes are presented.
 - (f) Completed.
 - (g) Results show that an awareness of the problems and phenomena involved make it possible to avoid most flow induced vibration problems.
 - (h) "Experiences of the Bureau of Reclamation With Flow-Induced Vibrations," by W. P. Simmons, Hydraulics Branch Report No. Hyd-538, Sept. 1964.
- (5334) SUDDEN ENLARGEMENT ENERGY DISSIPATORS.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) Limited studies under high heads were made to determine the effectiveness of a sudden enlargement type energy dissipator downstream from an 8-inch gate valve. The enlarged section started at the downstream flange of a 250 psi valve and was 16 inches in diameter by 80 inches long. Heads up to 600

- feet were imposed on the valve, which was operated over a range of openings. Back pressures of 1 to 7 feet were maintained on the enlargement downstream. Tests were made with and without admission of air into the upstream end of the enlargement.
- (f) Present phase completed.
 - (g) Results showed that excellent energy dissipation was achieved in the sudden enlargement section, and that very small back pressures of 1 to 7 feet were sufficient to hold the enlargement full of water.
 - (h) "Hydraulic Studies of a Sudden Enlargement Energy Dissipator Used Downstream From a Gate Valve," by W. P. Simmons, Hydraulics Branch Report No. Hyd-535, August, 1964.
- (5335) HIGH PRESSURE SLIDE GATE STUDIES FOR RUEDI AND MORROW POINT DAM OUTLET WORKS.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A 1:9 scale model is being used to determine operating characteristics and pressure conditions on slide gates to be used for regulation at heads up to 355 feet. The flow passages of the gates slope downward 30° in the direction of flow, and the gate leaves and bonnets are vertical. Effects of flaring the sidewalls immediately downstream from the leaf are being studied.
 - (g) Preliminary studies show that a gate slot design used very successfully on gates with horizontal flow passages and vertical leaves is not satisfactory for gates with 30° sloping passages and vertical leaves. Also, flaring the downstream walls in the normal fashion just downstream from the leaf leads to extremely subatmospheric pressure conditions and cavitation. By offsetting the walls abruptly 3 or 4 inches outward a very short distance downstream from the leaves, an excellent design with either parallel or diverging downstream walls is apparently obtained.
- (5336) BUTTERFLY VALVE STUDIES WITH CAVITATION OCCURRING.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A commercial 8-inch, 125 psi butterfly valve is being tested under portotype head to determine the effects on cavitation characteristics, air demand, and discharge coefficients that result from discharging the valve directly into sudden enlargements, or through short conduits into the enlargements. Tests are made with and without the admission of air, and quantities of air needed to just quiet the cavitation are being obtained. Effects of air admission on the discharge coefficient are also being obtained.
 - (g) Preliminary results show that satisfactory pressure reducing stations for high differential heads and low back pressures can be obtained with butterfly valves if the valves discharge directly into a 2.0 dia enlargement. Air in sufficient quantities to relieve cavitation when the discharge enters the enlargement directly, or through short sections of pipe, has little effect upon the discharge coefficient.
- (5337) PRESSURE RELIEF PANELS FOR OROVILLE DAM POWER PLANT INTAKE TOWERS.
- (b) California Dept. of Water Resources.
 - (c) California Dept. of Water Resources, Sacramento 2, Calif.
 - (d) Experimental; for design.
 - (e) The 40- by 42-foot temperature control shutters for the inclined intake towers are designed to withstand a maximum head differential of 5 feet of water. Under maximum discharge through the power plant the head differential across the shutters will be 3 feet. Surges caused by power plant demand fluctuations, or removal or replacement of temperature control shutters, could cause pressures across the shutters in excess of the design maximum allowable.
- (f) Completed.
 - (g) Relief panels have been designed which will open under a head differential of 3 1/2 feet. The recommended panel was calibrated to determine the number of panels required to furnish the discharge demand of the power plant for a maximum head differential of 5 feet of water.
 - (h) Report in preparation.
- (5338) LABORATORY TESTS OF GATE SEALS UNDER PROTOTYPE HEADS.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A facility for testing gate seals under heads of up to 200 feet was used on two similar double stem rubber gate seals. One seal bulb was capped with teflon and the other was uncapped. The program consisted of extrusion tests under sustained load, and tests with relative motion to determine the seals action as it approached, touched, and moved on the seat. A new facility is being designed to test seals at heads of approximately 600 feet.
 - (g) The teflon cap added to the rigidity of the seal and prevented much of the distortion noted with the uncapped seal. Also, when the seal was moved relative to the seat, the teflon cap prevented the seal from being pinched between the clamp bar and seal seat.
- (5339) MODEL-PROTOTYPE CORRELATION OF AIR DEMAND.
- (b) Field tests and laboratory project.
 - (d) Theoretical and experimental; applied research.
 - (e) Basic parameters are being developed to correlate model results with prototype measurements for the flow of air in a closed conduit partially filled with moving water. Prototype measurements are essentially complete. Laboratory tests are beginning in a variable slope, enclosed, rectangular channel. The mean air velocity and turbulence intensity of the air stream will be measured for various water velocities, various water depths and various pressure gradients.
- (5340) RUEDI DAM SPILLWAY AND OUTLET WORKS.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A 1:42 scale model was built to verify the hydraulic design of the spillway crest, chute, and stilling basin; the junction of the auxiliary outlet works with the spillway chute; the outlet works stilling basin; a bypass flume and stilling basin; and to investigate the required geometry and extent of downstream river channel improvement.
 - (f) Completed.
 - (g) Flow conditions throughout the structure were satisfactory. Erosion tests indicated that additional riprap was necessary near the bypass basin but that little or no riprap was necessary in the river channel. In other areas the specified riprap was adequate.
 - (h) "Hydraulic Model Studies of Ruedi Dam Spillway and Outlet Works," by U. J. Palde, Hydraulics Branch Report No. Hyd-534, October 1964.
- (5341) GRANBY DAM SPILLWAY.
- (b) Laboratory project.
 - (d) Experimental; for design.
 - (e) A 1:36 scale model was used to study the modification to the spillway chute and the proposed flip bucket and plunge basin for flows up to 12,000 cfs at velocities in the flip bucket ranging up to approximately 100 feet per second.
 - (f) Completed.
 - (g) A deflector and transition in the curved super elevated, horizontal portion of the chute was developed to provide good flow distribution in the flip bucket. The flip bucket and plunge basin were developed

to provide effective energy dissipation for flows up to 3,000 cfs and to prevent erosion in the area adjacent to the flip bucket for flows up to 12,000 cfs.

(h) Report in preparation.

(5342) SWIFT DAM SPILLWAY.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:42 scale model is being built to determine necessary modifications to rehabilitate a 46-year-old chute spillway.

(5343) STRATIFIED FLOW.

- (b) Laboratory project.
- (d) Library study.
- (e) Library research is being made to determine the extent of work that is being done and has been done in this field. An abstract will be prepared and a proposal made for laboratory research. Particular interest is being given to regulation of reservoir releases and the design of outlet works to maintain desirable oxygen balance in streams.

(5344) PORTAGE MOUNTAIN DAM LOW LEVEL OUTLET WORKS.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:24 scale model is being constructed to study the low level outlet works with two gate valves each discharging 3,750 cfs into a diversion tunnel. The outlet works flow discharging from the diversion tunnel into the river, will also be studied.

(5345) YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:8 scale model was constructed to study the stilling basin and diffuser chamber in the intake to the resting pool of the spawning channel.
- (f) Completed.
- (g) A slotted baffle for the stilling basin was developed to dissipate the energy of the incoming flow and to provide good flow distribution from the diffuser chamber into the resting pool.
- (h) Report in preparation.

(5346) GLEN ELDER DAM SPILLWAY.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:72 scale model is being used to study the hydraulic features of the spillway. The model contains 12 radial gate controlled spillway bays, the approach channel, surrounding topography, the hydraulic jump stilling basin and concrete lined apron, and a portion of the downstream channel.
- (g) The flow in the approach area, through the bays, and in the downstream channel is smooth. The operation of the stilling basin is efficient. There is no excessive erosion of the downstream channel. No major changes to the initial design were recommended as a result of the model study.
- (h) Report in preparation.

(5347) LITTLE PANOCHÉ CREEK DETENTION DAM OUTLET WORKS INTAKE STRUCTURE.

- (b) Laboratory project.
- (d) Experimental; for design.
- (e) A 1:15 scale model was built to study the flow conditions in a square, submerged vertical inlet and bend when stop logs are used to control the flow into the inlet.

U. S. DEPARTMENT OF THE NAVY, DAVID TAYLOR MODEL BASIN.

Inquiries concerning the following projects should be addressed to the Commanding Officer and Director, David Taylor Model Basin, Washington, D. C. 20007.

(1778) HYDRODYNAMIC NOISE.

- (b) Bureau of Ships; David Taylor Model Basin.
- (d) Hydrodynamic research.
- (e) Investigations of the characteristics of underwater noise associated with various hydrodynamic phenomena such as cavitation, bubble oscillations, surface disturbances, turbulence, and unsteady flow. Attention is now being given to measurement of spectra and space-time correlations of pressure fluctuations on walls adjacent to turbulent flows, such as curved plate boundary layer flows, turbulent boundary layers on buoyancy propelled bodies, and fully turbulent pipe flows.
- (g) Boundary layer pressure fluctuations on wall of three inch diameter pipe with air flow, have been determined with particular attention given to the low frequencies.

(1783) MATHEMATICAL SHIP LINES.

- (b) Bureau of Ships; David Taylor Model Basin.
- (d) Theoretical research.
- (e) Development of a suitable method for the mathematical determination of ship lines which can be applied to a wide variety of ship forms especially to those of modern design.
- (f) Inactive.
- (g) A method has been developed for the mathematical fairing of graphical lines. This is a first step toward the development of a flexible system of mathematical ship lines. Future work is directed toward the development of a system of mathematical lines which will permit the derivation of a hull form for a given set of parameters.

(1786) STUDIES OF THE SLAMMING OF SHIPS.

- (b) Bureau of Ships; David Taylor Model Basin.
- (d) Experimental and theoretical basic research.
- (e) Phase 1: Statistical study to clarify the basic nature of slamming phenomenon experienced by a ship in rough seas and to develop a method for predicting the frequency of occurrence of slamming as well as its severity.
- Phase 2: Computations and measurements of the pressure distribution and impact forces on the bottoms of slamming ship for the purpose of developing criteria to effect their reduction.
- (f) Phase 1: Active. Phase 2: Partially completed.
- (g) Phase 1: Basic nature of ship slamming phenomenon has been clarified by conducting tests on a MARINER model. Effects of sea severity, ship speed, course angle, and loading conditions on slamming were obtained. A theory for predicting the frequency of occurrence and severity of slamming has been developed.
- Phase 2: A theory which is applicable to almost any practical ship forebody section has been developed for determining impact force and pressures on ship's bottom during slamming. A two-dimensional drop test to evaluate the effect of sectional form on impact pressure was conducted for three different ship forms ranging from extreme U to extreme V form. A comparison between theoretical and experimental results was made on impact pressure.
- (h) Phase 1: "Prediction of Occurrence and Severity of Ship Slamming at Sea", Michel K. Ochi. Fifth Symposium on Naval Hydromechanics, September 1964.
- "Extreme Behavior of a Ship in Rough Seas", Michel K. Ochi. Transaction of the Society of Naval Architects and Marine Engineers, Vol. 72, 1964.
- Phase 2: "Hydrodynamic Impact with Application to Ship Slamming", K. M. Ochi and M. D.

Bledsoe. Fourth Symposium on Naval Hydrodynamics, August 1962.
 "Two-dimensional Experiments on the Effect of Hull Forms on Hydrodynamic Impact", in preparation.

(2229) NEAR SURFACE EFFECTS.

- (b) Bureau of Ships; David Taylor Model Basin. Hydrodynamic research.
- (d) A mathematical study of the forces and moments acting on bodies due to the proximity of a free surface. The studies include both the case in which the surface is initially undisturbed and the case in which there are disturbances originating at a distance. Experiments are being conducted to verify the theoretical developments.
- (e) Methods were developed for computing the forces and moments acting on bodies of revolution, both due to waves generated by the body itself and to regular trains of waves. Experiments with a spheroid moving under waves largely confirmed the theory except in following seas. The damping forces on a submerged translating ellipsoid which is oscillating in any of its six degrees of freedom have been developed theoretically. The effect of tank walls has been evaluated theoretically as well. Theoretical methods have been developed for the determination of wave resistance of floating bodies in steady motion from wave measurements along a parallel cut. The first and second order diffraction and radiation forces acting on a submerged two-dimensional circular cylinder have been developed and computations have been made. Analytic expressions have been obtained for arbitrary bodies relating the radiation and diffraction forces to each other. For a submerged, translating, two-dimensional cylinder, it has been shown that second-order forces due to nonlinearity of the free surface boundary conditions are comparable to second order forces resulting from exact satisfaction of the body boundary conditions. Formulas have been derived for the sinkage and trim of ships moving in shallow water. These agree well with experiments except for speeds near to the shallow water critical speed.

(2230) THEORY OF SEAWORTHINESS.

- (b) Bureau of Ships; David Taylor Model Basin. Hydrodynamic research.
- (d) A theoretical study, with experimental confirmation, of the factors affecting the seaworthiness of ships, for the purpose of developing procedures for predicting their motions.
- (e) Theoretical results for ship motions based on the "thin-ship" idealization have generally proved to be either inaccurate or incomplete. Recent results from application of slender body theory have shown good agreement with experiments at zero speed of advance. The corresponding theory has been developed for non-zero speeds, but calculations have not yet been made, and so it is not known whether the success at zero speed can be extended to the more general situation. Improved methods of testing ship models have been developed, and the entire frequency response of a ship at a single speed can be determined from one test run. The form of the equations of motion have been obtained by a very general theoretical approach. These equations are characterized by the appearance of convolution integrals involving the entire past history of the motion; they are free of the usual frequency-dependent coefficients. Tests have been conducted to characterize the dynamics of a ship, relating the

kernels of these convolution integrals to the common added mass and damping coefficients. A survey of ship-motion theory has been prepared.

- (h) "The Impulse Response Function and Ship Motions," by W. E. Cummins, Schiffstechnik, 9, 101-109 (1962). Also available as DTMB Report 1661.
 "Pulse Methods for Determining Ship Motions," by W. E. Cummins and W. E. Smith, Fifth ONR Symposium on Naval Hydrodynamics, 1964.
 "Recent Progress Toward the Understanding and Prediction of Ship Motions," by T. Francis Ogilvie, Fifth ONR Symposium on Naval Hydrodynamics, 1964.
 "A Slender-Body Theory for Ship Oscillations in Waves," by J. N. Newman, Journal of Fluid Mechanics, 18, 602-618 (1964).
 "Current Progress in the Slender Body Theory for Ship Motions," by J. N. Newman and E. O. Tuck, Fifth ONR Symposium on Naval Hydrodynamics, 1964.
 "Testing Ship Models with Transient Waves," by M. C. Davis and E. E. Zarnick, Fifth ONR Symposium on Naval Hydrodynamics, 1964.
- (2237) LIFTING SURFACE THEORY OF PROPELLERS.
 - (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Theoretical; applied research.
 - (e) Studies of the corrections on lifting line theory which arise from the finite extent of the blades.
 - (h) "Hydrodynamic Aspects of Propeller Design Based on Lifting Surface Theory, Part I: Uniform Cord-Wise Load Distribution," H. M. Cheng, DTMB Report 1802 (Aug. 1964).
- (2971) FULL SCALE TRIALS AND MODEL PREDICTION CORRELATION.
 - (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental testing and re-evaluation of existing test data.
 - (e) The accuracy of full scale power predictions from model test results depends upon the proper selection of the correlation allowance (ΔC_p) to be used in model tests. The results of about 54 correlations of surface ships have been completed and published. The present target is the analysis of correlations submarines, considering all trials conducted, and selecting those most acceptable to this program.
 - (g) Same analysis has been done in connection with submarines. Further analysis of the data derived from the surface ship trials is continuing.
- (3284) UNSTEADY HYDROFOILS.
 - (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental and theoretical applied research.
 - (e) This work will provide hydrofoil design criteria for the Bureau of Ships to be used in designing high speed, sea-going hydrofoil craft. The forces on two-dimensional hydrofoils due to heaving and pitching oscillations of the foil, and due to encounters with regular, head and following waves will be determined experimentally. Both cavitating and non-cavitating conditions will be studied. The data from the experiment will be digitized and then will be analyzed on the IBM 7090 computer using existing thesis.
 - (g) All of the experimental equipment has been assembled and its operation checked. Experimental runs have been made on a subcavitating, NACA 16-209 profile hydrofoil model. Preliminary experimental runs have been made on a supercavitating flat plate hydrofoil model. A pressure distribution model is planned. Several equipment and analysis reports are being prepared for publication.
 - (h) "A Multichannel Digital Data Acquisition

- System", by James A. Luistro, TMB Report 163C, iv, 55 p. illus., diagrs., tables, graphs, refs. Sept. 1964.
 "Calculated Hydrodynamic Loads on an Oscillating Hydrofoil", by T. J. Langan and D. Coder, TMB Report 1695 (in review).
 "Survey of Steady Lift Force and Moment on Two-Dimensional Flat Plate Hydrofoils Beneath a Free Surface at Various Cavitation Numbers", by J. H. Pattison, TMB Report 1776, (in review).
- (3285) HYDROELASTICITY PROBLEMS.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental and Theoretical Applied Research.
 - (e) Investigations to determine the conditions which produce hydroelastic instability of oscillatory hydrofoil systems. The effects of speed, frequencies, mass distribution, cavitation, free surface and waves on the system stability will be studied. This work is related to Unsteady Hydrofoils (Reference No. 3284.)
 - (g) A flutter dynamotor for a two-dimensional, two-degree of freedom hydrofoil has been constructed. Flutter tests of a sub-cavitating hydrofoil are under way in the 36 inch Water Tunnel and on the High Speed Towing Carriage.
- (3286) SUPERCAVITATING PROPELLER DEVELOPMENT.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Theoretical and experimental; applied research.
 - (e) Studies and design of propellers designed to operate at high speeds including improved section shapes for good operating characteristics and better strength capability.
 - (g) Theoretical series for preliminary design purposes have been computed and published. Crashback and windmilling performance has been experimentally obtained. Experiments with a controllable pitch supercavitating propeller have confirmed the feasibility of this type of propulsion device.
- (3292) EXPLORATORY STUDIES AND PLANS AT DTMB FOR MODEL TESTS IN 3-DIMENSIONS.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental; basic research.
 - (e) A new seakeeping test facility is now in operation. Techniques for generating irregular short-crested seas and measuring the response of ship models at oblique headings is under development.
 - (g) Segmented wave generators provide the ability to produce oblique waves. Programming to individual wavemakers results in generation of confused seas of almost any nature. The rectangular basin offers opportunity to test in any relative heading to the waves and even in cross seas. Problems in analysis involve determination of the seaway (in the tank) as a function of frequency and direction. Ship motions in confused seas will be random in nature and will be analyzed by spectrum methods.
- (3617) VENTILATED PROPELLER DEVELOPMENT.
- (b) David Taylor Model Basin.
 - (d) Theoretical and experimental; applied research.
 - (e) Studies and design of ventilated propellers for operation at intermediate speeds.
 - (g) Experiments on the use of tripping wedge and tripping wire have been performed. The wedge appears to be no better than the wire and causes a loss in performance. Work on measurements of ventilated cavities is progressing.
- (3619) VERTICAL AXIS PROPELLER.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental and theoretical; applied research.
 - (e) Theoretical and experimental studies of performance characteristics of various types of vertical axis propellers.
- (4426) DEVELOPMENT OF A LOW WAVE DRAG HULL FORM.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Basic research.
 - (e) To establish a series of basic hull forms which can be used as a guide to evaluate the merit of future high speed ship designs.
 - (g) Results of resistance tests of 27 models of conventional hull form up to speed-length ratio of 5-0 has been reported.
 - (h) "Series 64 Resistance on High Speed Displacement Forms", by Hugh Y. Yeh. Presented before the Chesapeake Section of the Society of Naval Architects and Marine Engineers. Dec. 1964.
- (4427) A METHOD OF CALCULATING SPINDLE TORQUE OF CONTROLLABLE PITCH PROPELLERS.
- (b) David Taylor Model Basin.
 - (d) Theoretical; applied research.
 - (e) A method of calculating the spindle torque of a controllable pitch propeller over the complete range of operating conditions and a theoretical investigation of the effect of various design parameters upon spindle torque. In order to calculate spindle torque at off design conditions, the off design performance of the controllable pitch propeller must first be determined.
 - (g) A method of calculating the spindle torque at design conditions has been completed. The geometric problem of determining the effective distortion of blade sections at off design pitch settings has been solved. The solution has been programmed for the 7090 Computer.
- (4428) COMPUTER SOLUTIONS OF FREE SURFACE FORCES.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Hydrodynamic research.
 - (e) The linearized potential problem of a body oscillating on the free surface will be solved directly on a digital computer by distributing pulsating sources over the surface of the body and calculating the required source density. The individual source potentials are chosen to satisfy the free surface boundary condition.
 - (g) The integral equations for the case of two dimensional bodies have been approximated by algebraic equations. Solutions have been obtained for heave, sway, and roll motions of several bodies. Forces and moments have been calculated.
- (4429) LATERAL FORCES.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Hydrodynamic research.
 - (e) The lateral force on a translating body which vertically cuts the free surface is being formulated theoretically. Two special cases are included: (a) If the draft is large compared to the length, the body is a strut with angle of attack. (b) If the draft is very small, the body corresponds to a yawed thin ship.
 - (f) Suspended.
 - (g) An integral equation has been derived for the density of a surface distribution of dipoles, such that the boundary conditions are satisfied.
- (4809) TURBULENT BOUNDARY LAYERS IN PRESSURE GRADIENTS ON ROUGH SURFACES.
- (b) Laboratory project, David Taylor Model Basin.
 - (d) Theoretical and experimental; basic and applied research.
 - (e) Research in behavior of turbulent boundary layers in pressure gradients leading to separation. Initial roughnesses will be screens of various gages fastened to wall of wind tunnel. Velocity surveys and

- (g) turbulence measurements will be performed. Data have been obtained, with one wall thickness, at moderate and high pressure gradients and at zero pressure gradient. Boundary layer velocity profiles were obtained with a pitot tube and hot wire. Longitudinal turbulent intensities were measured with a hot wire. Measurements were made at numerous longitudinal positions along the wall. Measurements are now in progress with a high pressure gradient with induced separation.
- (4810) SHIP WAKE SIMULATION STUDIES.
- (b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical; applied research.
(e) To produce ship wake distributions in a variable pressure water tunnel in order to determine the performance of propellers in non-uniform wake flows.
(g) A theoretical method has been obtained for determining the wire grid geometry necessary to produce arbitrary, steady, three-dimensional flows. Simple experimental confirmation of the method has been obtained.
- (4811) STEADY-STATE FORCES ON SUPERCAVITATING AND VENTILATED HYDROFOILS.
- (b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical and experimental; applied research.
(e) To study the steady-state lift and drag characteristics of supercavitating hydrofoil configurations for application to hydrofoil craft and supercavitating propeller design.
(g) Experimental determination of the lift and drag of various three-dimensional supercavitating hydrofoils is in progress. These include foils with 2-term, 5-term and flat-faced sections. The effects of aspect-ratio and taper are being investigated. Ventilation by blowing air through holes in the suction surface of the foil is used to extend the range of cavitation number. Future research includes the determination of two-dimensional lift and drag, studies of flap configurations and measurement of the interaction of tandem and cascade foils.
(h) "Supercavitating and Ventilated Performance of Three Hydrofoil Sections" by G. F. Dobay and N. L. Picken. TMB Report 1828, Jan. 1964.
- (4812) PROPELLER AND BODY INTERACTION.
- (b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical and experimental; applied research.
(e) Study and development of design criteria for determining propulsion characteristics of submerged bodies and hydrofoil-supported craft.
(g) Axial clearance between a submerged body of revolution and a stern propeller has been optimized on the basis of propulsive coefficient. A method has been developed for computing thrust deduction for submerged hydrofoil-propeller arrangements.
(h) "Induced Velocity Field of a Fully Cavitating Propeller and Interaction Experiments with a Fully Cavitating Propeller Behind a Hydrofoil", J. L. Beveridge. TMB Report 1832, April 1964.
- (4813) INVESTIGATION OF DUCTED PROPELLERS.
- (b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical and experimental; applied research.
(e) To develop a design method for ducted propellers and to conduct a parametric study of ducted propeller performance.
(g) A theory of the ducted propeller with finite number of blades has been developed. From this theory a design method will be developed and then a parametric study of ducted propeller performance will be conducted.
- (4814) POWERING IN WAVES.
- (b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental.
(e) To determine the powering characteristics and speed loss of ships in waves by conducting model tests in regular and irregular waves. Limitations of present procedures for predicting power and speed loss in a seaway from tests in regular waves will be determined and new techniques will be developed where necessary.
(f) Cancelled.
- (4815) PARAMETRIC STUDIES.
- (b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental.
(e) To provide basic information from which the most suitable destroyer form for high sustained sea speeds in a seaway can be established. Model tests will be conducted in regular and irregular seas using a series of models for which the significant geometric parameters are systematically varied. Motions and powering increase in waves will be studied.
(f) Cancelled.
- (4816) FUNDAMENTAL PROPERTIES OF SHIP ROLLING.
- (b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical.
(e) Though extensive studies of rolling have been made in recent years, a great deal remains to be learned concerning the fundamental properties of rolling for both surface ships and submarines. Areas which require additional research are (1) applicability of superposition principle for rolling motion especially in short crested waves, (2) unstable rolling motion in oblique regular and in irregular waves, (3) nonlinear roll behavior in rough seas, etc. In order to clarify the fundamental nature of rolling, forced oscillation tests as well as model tests in regular and irregular waves will be conducted. Parameters significant for roll will be investigated.
- (5121) SERIES 60 - PROPELLER INDUCED VIBRATION.
- (b) David Taylor Model Basin.
(d) Experimental; basic research.
(e) Measurement of propeller induced vibratory forces to study the effect of fore and aft clearance in the propeller aperture of the clearwater type. The effect of number of blades and the tip clearance will also be determined. In addition, the pressure transmitted and shaft transmitted forces will be measured independently to determine the significance of each.
(g) The instrumentation and test techniques for measuring the propeller induced vibratory forces on a single screw ship model has been developed sufficiently to obtain repetitive results. Although there is insufficient information available to permit extrapolation to full scale forces, comparison of test results of models of similar type and dimensions appears valid. Measurements of instantaneous pressures have been made on the hull of the SS Esso GETTYSBURG. This data are being analyzed and it is anticipated that correlation will be performed through model tests.
- (5122) FLOW VISUALIZATION STUDIES.
- (b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental; applied research.
(e) To visually determine in water the effect of boundary-layer growth and trailing edge geometry on separation, and the mechanism of vortex shedding, from stationary and oscillating hydrofoil shapes.
(g) The hydrogen bubble visualization technique has been adopted to the 12-INCH water tunnel and preliminary flow studies have been made on a number of two-dimensional bodies. The

experiments are being extended to study vortex shedding from stationary foils having different trailing edge geometrics.

from laminar to turbulent flow for bodies of revolution.

- (5123) THE EFFECT OF GAS NUCLEI ON CAVITATION.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental; applied research.
 - (e) To determine the effect of gas nuclei on the inception of cavitation.
 - (g) Acoustic techniques to measure the distribution and size of nuclei are being studied, and one will be applied to the water tunnels at DTMB. Cavitation inception studies will be made for a simple body and propellers and the results correlated with gas nuclei content of the water.
- (5124) PROPELLER OSCILLATING PRESSURE FIELD.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental; applied research.
 - (e) To experimentally determine the oscillating pressure field about marine propellers and correlate these measurements with theoretical predictions.
 - (g) Pressures have been measured on a flat plate parallel to the axis of two propellers, one a propeller of conventional design and the other of double blade thickness, in both uniform and non-uniform flow.
- (5125) HYDRODYNAMICALLY EXCITED PROPELLER SINGING.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental; applied research.
 - (e) To determine the characteristics of flow induced propeller singing and investigate methods to suppress singing.
 - (g) Tests on a model propeller have demonstrated the feasibility of studying singing at model scale by suitable trailing edge modifications. The investigation will be extended to determine the applicability of two-dimensional flow-excited vibration data to propeller blades and to study the influence of variations in trailing edge geometry and other design parameters on propeller singing.
 - (h) "Vortex Induced Propeller Blade Vibration: Some Aspects of the Problem", R. A. Cumming, TMB Report 1838, June 1964.
- (5126) CAVITATION INCEPTION ON A ROUGH SURFACE.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental and theoretical; applied research.
 - (e) An investigation of cavitation inception over isolated three-dimensional roughness elements on a flat plate as a function of boundary-layer parameters, pressure gradient, geometry and size of the roughness elements, etc. Theoretical studies will attempt to establish scaling laws for cavitation.
 - (g) Equipment has been built and assembled. Testing will start toward the end of 1964.
- (5127) INTERACTION FORCES BETWEEN LIFTING SURFACES.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Theoretical; applied research.
 - (e) A two-dimensional theory for determining the forces and moments acting on two lifting surfaces as one passes through the wake of the other will be developed. This theory will be applied to the prediction of propeller-appendage interaction forces on a ship.
 - (g) The theoretical analysis has been formulated and a computer program for solving the integral equations is being written in FORTRAN.
- (5128) BOUNDARY-LAYER STUDIES.
- (b) David Taylor Model Basin; basic and applied research.
 - (d) Theoretical and experimental; basic and applied research.
 - (e) Studies of boundary-layer phenomena important to naval hydrodynamics; methods of reducing frictional resistance, prediction of transition
- (5324) CAVITY FLOW STUDIES.
- (b) Bureau of Ships; David Taylor Model Basin.
 - (d) Experimental and theoretical, basic research.
 - (e) A study of the vortex shedding phenomenon recently observed in fully cavitating flow. The study comprises (1) The experimental investigation of the dependence on cavitation number and ventilation index of a modified Strouhal number for simple two-dimensional bodies; (2) the development of a new mathematical model for cavity flows; and (3) the investigation of the relationship between vortex shedding and hydrofoil oscillation. The purpose is to gain more understanding of cavity flows.
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U. S. DEPARTMENT OF THE NAVY, NAVAL BOILER AND TURBINE LABORATORY.

- (3623) HIGH PRESSURE-TEMPERATURE WATER FLOW METER CALIBRATION.
 - (b) Bureau of Ships; Philadelphia Naval Shipyard (Naval Boiler and Turbine Laboratory).
 - (c) Mr. J. W. Murdock, Associate Technical Director for Applied Physics Division, Naval Boiler and Turbine Laboratory, Phila. Naval Shipyard, Phila. 12, Pennsylvania.
 - (d) Experimental; applied research.
 - (e) A facility is available for calibrating with water at pressures and temperatures up to 2500 psi and 600 F respectively. Capacity is 100 gpm at maximum pressure and temperature and greater at lower pressures and temperatures. After flowing through the metering section the water is cooled and weighed. The facility is also used to investigate and verify orifice meter coefficients at pressures and temperatures above those at which the coefficients in use were established. A number of flow meters which measure the flow in nuclear reactor loops have been calibrated.
 - (f) Inactive.
 - (g) A limited amount of test data indicate good agreement between orifice flow rates obtained by calibration at high pressures and temperatures and those obtained by extrapolating from cold water calibrations. Other meter tests show the need to include suitable corrections for change in shape, size, density, etc.
- (3624) INVESTIGATION OF ELBOW FLOW METERS.
 - (b) Bureau of Ships; Philadelphia Naval Shipyard; (Naval Boiler and Turbine Laboratory).
 - (c) Mr. J. W. Murdock, Head, Applied Physics Division, Naval Boiler and Turbine Lab., Phila. Naval Shipyard, Phila. 12, Pa.
 - (d) Experimental, applied research.
 - (e) The 90 degree elbow has been proposed for metering flow in shipboard systems. This type meter is attractive since the use of an existing elbow would not require any changes to the piping and would impose no additional pressure drop on the system. In addition, the elbow can meter reverse flow. The chief drawbacks are large variation in elbows and the lack of an exact relationship between flow and differential pressure. Testing was limited to the long turn 90 degree, type A elbows of Specification MIL-F-1183 to establish criteria for their installation and use.
 - (f) Completed.
 - (g) When certain standards are imposed on the fabrication and measurement of the elbows

and a specified means of computing flow is used, a measurement tolerance of 4 percent can be expected. In control applications the elbow meter was found to have a square root transfer function and a repeatability of 0.2%. "Performance Characteristics of Elbow Flow Meters", Transactions of the ASME, Journal of Basic Engineering, Vol. 86, No. 3, 498-506, Sept. 1964.

- (4001) HIGH PRESSURE STEAM AND WATER FLOW TESTS.
 - (b) American Society of Mechanical Engineers.
 - (c) Research Committee on Fluid Meters, American Society of Mechanical Engineers, 345 East Forty-Seventh Street, New York 17, New York. Experimental; applied research.
 - (d) Although the ASME Research Committee on Fluid Meters has sponsored many fundamental research programs dealing with the development of basic constants used with primary elements, hardly any of this work has been done on steam flow at high pressures and temperatures. Neither has research been done on high temperature water flow. Analysis of many tests indicate that the basic calibrations obtained with low temperature water (air and gas) could be extrapolated with high accuracy to the measurement of high pressure and temperature steam and water flow provided suitable corrections were made for the change in the shape and size of the primary element, the pipe and the fluid. This procedure has been experimentally verified for steam up to 2000 psi and 1050 F and for water to 2500 psi and 600 F.
 - (f) Completed.
 - (g) Nozzles and orifices were calibrated with water at 240 F, 2200 psia, and with steam at 1050 F, 2000 psia. Pipe Reynolds numbers averaged 600,000 for the water and 4,000,000 for the steam. Coefficients were generally in agreement with ASME predicted coefficients. Two and a quarter percent (2 1/4%) chromomolybdenum steel proved unsatisfactory for the steam nozzles showing rusting and pitting after less than 10 hours. Type 430 stainless steel was substituted and was satisfactory.
 - (h) Final report to be presented during Nov.-Dec. annual meeting of ASME Fluid Meters Committee, (ASME Paper No. 64-WA/FM-4.

- (5286) MEASUREMENT OF ACOUSTIC VELOCITY OF STEAM.
 - (b) Joint research project, Naval Boiler and Turbine Laboratory and Office of Naval Research.
 - (c) Mr. J. W. Murdock, Head, Applied Physics Division, Naval Boiler and Turbine Laboratory, Phila. Naval Shipyard, Phila., Pa. 19112.
 - (d) Experimental; basic research.
 - (e) Objective is to obtain precise knowledge of acoustic velocity values for steam in liquid-vapor and vapor phase. Data will be obtained with steam pressures and temperatures up to 5000 psi and 800F respectively.

U. S. NAVAL ORDNANCE LABORATORY.

- (4867) THE HYDROBALLISTICS OF WATER ENTRY.
 - (b) Bureau of Naval Weapons, Department of the Navy.
 - (c) Commander, U. S. Naval Ordnance Laboratory White Oak, Silver Spring, Maryland.
 - (d) Experimental, theoretical, basic and applied research.
 - (e) The purpose is to study high velocity water entry as related directly or indirectly to the behavior of missiles. The study includes the stability and forces during the entry, cavity development and pressure, and the missile trajectory. A wide range of developmental and research configurations

and of experimental conditions are investigated. Guns are used to launch models into a tank equipped for operation at various pressures. A large tank facility is being constructed for experimental projects such as water entry, water exit, and trajectory studies. In this tank the pressure of the gas above the water will be reducible for water-entry scaling.

U. S. NAVAL ORDNANCE TEST STATION.

(4002) MISSILE BEHAVIOR DURING WATER EXIT.

- (b) Bureau of Naval Weapons, Navy Department.
- (c) Commander, U. S. Naval Ordnance Test Station, Attn: Dr. John G. Waugh, Code P8074, 3202 E. Foothill Blvd., Pasadena, California.
- (d) Experimental; basic research.
- (e) The objectives of this project are as follows:
(1) To study missile water-exit behavior and associated phenomena under different conditions to determine if problems exist in missile water-exit technology and to establish scaling techniques for modeling missile water-exit behavior. (2) To evaluate qualitatively the inherent value of slender-body theory in predicting the underwater and water-exit behavior of an underwater launched missile in the presence of various sea states.
- (g) Studies have been made on the water-exit behavior of a momentum-propelled 2-inch-diameter hemisphere-head missile under different degrees of cavitation, ranging from fully wetted to fully cavitating, and for a range of trajectory water-exit angles. The results indicate that considerable perturbations in missile pitch and pitch velocity take place at water exit, and it is inferred that problems may exist in missile water-exit technology.
The experimental fully-wetted flight and water-exit behavior of a blunt based axisymmetric missile traveling in a standing wave are simulated on an analogue computer using motion equations derived from slender-body theory. The analytical approach is supplemented by introducing experimental hydrodynamic coefficients and transverse drag terms. The results of the simulation are compared graphically with the experimental behavior to illustrate an upper limit of the accuracy to be expected of slender-body theory.
- (h) "The Variable-Angle Variable-Pressure Launching Tank" by J. G. Waugh. Article published in "Cavitation Research Facilities and Techniques," 1964, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 St., New York, N. Y. "A Qualitative Correlation of Theoretically Predicted and Experimentally Obtained Underwater-Launched Missile Behavior in the Presence of Waves," by M. L. Sturgeon and J. G. Waugh, (being edited for publication).

(4434) DUCTED PROPELLER DESIGN.

- (b) Bureau of Naval Weapons, Navy Department.
- (c) Commander, U. S. Naval Ordnance Test Sta., Attn: Mr. J. F. Reynolds, Code P8074, 3202 East Foothill Blvd., Pasadena, Calif.
- (d) Theoretical; applied research.
- (e) This project is concerned with solutions to the boundary flow equations for various mathematical models which may be used to describe a shrouded or ducted propeller system. The models under investigation assume an inlet velocity profile and involve iterative solutions to the boundary condition on central bodies and shrouds with camber and thickness. The iterations also include the effects of a finite bladed propeller on the boundary condition for both the shroud and central body. The

solution represented by the source and vortex density describing the boundary flow equations is then used to solve the equations describing the induced flow through the model.

- (g) Computer programs are available on an IBM 7094 describing the effects of shroud camber, thickness and the average propeller velocities on the shroud loading and shroud-induced flow.

(4868) NON-NEWTONIAN FLUIDS.

- (b) Bureau of Naval Weapons, Department of the Navy.
- (c) Commander, U.S. Naval Ordnance Test Station, Attn: J. W. Hoyt, Code P807, 3202 E. Foothill Boulevard, Pasadena 8, California.
- (d) Experimental; basic research.
- (e) The turbulent flow characteristics of dilute solutions of various high polymers are being studied to understand why they often display anomalous flow behavior.
- (g) Pipe flow tests and chemistry studies are being made of high polymers which seem to reduce the intensity of turbulence.
- (h) "The Effects of Additives on Fluid Friction," by J. W. Hoyt and A. G. Fabula. ONR Fifth Symposium on Naval Hydrodynamics, Bergen, Norway, Sept. 1964. (Also to appear as NAVWEPS Report 8636).

(4872) A METHOD FOR COMPUTING TURBULENT BOUNDARY LAYERS BASED ON THE LAW OF THE WALL AND THE LAW OF THE WAKE.

- (b) Bureau of Naval Weapons, Navy Department.
- (c) Commander, U. S. Naval Ordnance Test Station Attn: Mr. David M. Nelson, Code P8074, 3202 E. Foothill Boulevard, Pasadena 8, California.
- (d) Theoretical; applied research.
- (e) A method for computing turbulent boundary layers based on the law of the wall and Coles' law of wake is under development. This method is applicable to two dimensional bodies and to bodies of revolution in axial-symmetric flow where the boundary layer thickness is not necessarily small compared to the body radius. A simultaneous solution of the momentum integral equation and the energy integral equation is carried out assuming the mean velocity profiles are given by a universal, two-parameter representation as suggested by Coles. The computational procedure will be programmed for an IBM 7090 computer.
- (g) All theoretical work has been finished and the computer programming is nearing completion.
- (h) "A Turbulent Boundary-Layer Calculation Method Based on the Law of the Wall and the Law of the Wake," by D. M. Nelson. NAVWEPS Report 8510, NOTS TP 3493, U. S. Naval Ordnance Test Station, China Lake, California.

(4873) RING WING LOADINGS.

- (b) Bureau of Naval Weapons, Navy Department.
- (c) Commander, U. S. Naval Ordnance Test Station, Attn: J. F. Reynolds, Code P8074, 3202 East Foothill Blvd., Pasadena 8, Calif.
- (d) Theoretical; applied research.
- (e) A study of the effect of the ring wing chord-diameter ratio on lift and pitching moments due to normal forces for isolated three-dimensional wings at angle of attack has recently been published. A second report to be published later includes the effect of axial forces on the total pitching moment and position of the wing aerodynamic center. It was found that, relative to two-dimensional airfoils, the effective position of aerodynamic center is changed significantly due to curvature of the chord plane and the axial forces due to wing camber and wing half cone angle.
- (h) "Pitching Moment Corrections from Axial

Forces on Isolated Ring Wings at Angle of Attack," J. F. Reynolds, NAVWEPS Report 8667, NOTS TP 3714.

(4919) RELATIVE FLOW AT LIFTING LINE FOR COUNTER ROTATING PROPELLERS.

- (b) Bureau of Naval Weapons, Navy Department.
- (c) Commander, U. S. Naval Ordnance Test Station, Attn: Mr. David M. Nelson, Code P8074, 3202 East Foothill Blvd., Pasadena, Calif.
- (d) Theoretical; applied research.
- (e) A theoretical means for determining the relative flow at the lifting line for counter rotating propellers is being developed and programmed for an IBM 7090 computer. This method is intended to handle non-optimum, wake-adapted propellers. The induced velocities at the lifting line arising from the effect of the front or rear propeller on itself are determined by a slightly modified version of the induction factor method developed by Lerbs.* The mean axial velocities at one propeller induced by the other are determined by replacing the finitely bladed propeller by an infinitely bladed propeller having the same radial thrust distribution and operating in the same wake. The mean tangential velocities at the rear propeller induced by the front propeller are determined by Stokes' theorem. The effect of the tapering afterbody on which the propellers are located is approximately accounted for by continuity consideration.
* "Moderately Loaded Propellers with a Finite Number of Blades and Arbitrary Distribution of Circulation," by G. W. Lerbs, Trans. SNAME, Vol. 60, 1952, pp. 73-117.
- (f) Completed.
- (g) This work is being incorporated into a lifting-surface propeller design method for counter-rotating propellers which is described in another section.

(4920) UNDERWATER GAS-JET PROPULSION STUDY.

- (b) Bureau of Naval Weapons, Dept. of the Navy.
- (c) Commander, U. S. Naval Ordnance Test Station, 3202 E. Foothill Blvd. Pasadena 8, Calif. Attn: H. V. L. Patrick or T. G. Lang, Code P5006.
- (d) Experimental; applied research.
- (e) The thrust and efficiency of a submerged supersonic gas-jet propulsion system will be studied on a model propelled by a solid propellant grain generating hot gas at 4,000 psi exhausted through four nozzles along its afterbody. The efficiency of the momentum exchange with the surrounding water will be studied in an effort to increase the normally low propulsion efficiency of high speed jets.
- (g) The test model has been constructed and statically fired. Propulsion tests at speeds to 40 knots in a ring channel are scheduled.

(5381) BASE-VENTED TORPEDO STUDY.

- (b) Bureau of Naval Weapons, Dept. of the Navy.
- (c) Commander, U. S. Naval Ordnance Test Station, Attn: H. V. L. Patrick or T. G. Lang, Code P5006, 3202 E. Foothill Boulevard, Pasadena 8, California.
- (d) Experimental; applied research.
- (e) The drag of several truncated torpedo models with air exhausted through their bases is measured as a function of gas flow rate, water tunnel speed, and angle of attack. Cavity pressure is also measured.
- (f) Completed.
- (g) The drag of all models remained the same as that of a streamlined model for truncations up to 90% of the maximum diameter, one of the models was fully base vented.
- (h) Two reports in process.

(5382) DROP TESTS OF OBJECTS IN A HIGH-POLYMER SOLUTION.

- (b) Bureau of Naval Weapons, Dept. of the Navy.

- (c) Commander, U. S. Naval Ordnance Test Station, Attn: H. V. L. Patrick or T. G. Lang, Code P5006, M. A. Ruszczycky, Code P8076, 3202 E. Foothill Boulevard, Pasadena 8, California.
- (d) Experimental; applied research.
- (e) In the first experiments, twenty-five small objects were dropped in a tank of water with zero, 200, and 1000 wppm of Polyox additive. The majority of the objects were spheres and cones. A second series of tests has been completed to determine whether high-polymer solutions, in relatively high concentrations, (up to 1.5%), affect the velocity of steel spheres falling at laminar-separation flow conditions.
- (g) In the first series of tests the drag of spheres up to a 1-inch diameter remained unaffected, as was the drag of the cones. The drag of spheres ranging from 1 to 2-1/2 inches in diameter was reduced up to 40%; however, significant wall interference occurred so the results are difficult to interpret without additional information. In the second series, different diameter spheres dropped in high-polymer solutions showed definite velocity increases over that obtained in water. Within the sphere sizes tested, the apparent drag reduction noted was 35.5%. The increased viscosity effect accounts for only about 18% reduction in drag. The highest Reynolds number reached in the tests was 5.19×10^4 , based on water; and from this it was concluded that all the steel spheres in the tests experienced laminar-separation flow only.
- (h) "Sphere Drop Tests in High Polymer Solutions" by M. A. Ruszczycky, unpublished report.

(5383) COLLAPSE OF GAS FILLED BUBBLES AGAINST A RIGID BOUNDARY.

- (b) Bureau of Naval Weapons, Dept. of the Navy.
- (c) Commander, U. S. Naval Ordnance Test Station, Attn: A. O. Musolf, Code P8076, 3202 E. Foothill Boulevard, Pasadena 8, Calif.
- (d) Experimental research.
- (e) The investigation of a high velocity water jet formed during the collapse of small cavitation bubbles is extended to larger, 6-inch maximum diameter, explosively formed bubbles. High speed motion pictures and resilient boundaries clearly show that the jet is capable of imparting a large force to the boundary.
- (f) Work is partially completed.

(5384) LIFTING-SURFACE DESIGN METHOD FOR COUNTER-ROTATING PROPELLERS.

- (b) Bureau of Naval Weapons, Dept. of the Navy.
- (c) Commander, U. S. Naval Ordnance Test Station, Attn: Mr. David M. Nelson, Code P8074, 3202 E. Foothill Blvd., Pasadena 8, Calif.
- (d) Theoretical; applied research.
- (e) The lifting-surface propeller design method for single-rotating propellers developed at the U. S. Naval Ordnance Test Station is being extended to counter-rotating propellers. The lifting line solution for counter-rotating propellers described in Section 4919 serves as the starting point for the lifting surface solution. The camber lines and pitch angles are computed as for the single-rotating propeller except the variation across the chord of the axial component of the interference velocities (velocities induced at one propeller by the other) is accounted for.
- (h) "A Lifting Surface Propeller Design Method for High Speed Computers," by D. M. Nelson. NAVWEPS Report 8442, NOTS TP 3399, U. S. Naval Ordnance Test Station, China Lake, California, January 1964.

(5385) DETERMINATION OF THE HYDRODYNAMIC COEFFICIENTS OF BODIES OF REVOLUTION USING THE DOUGLAS POTENTIAL FLOW PROGRAMS.

- (b) Bureau of Naval Weapons, Dept. of the Navy.
- (c) Commander, U. S. Naval Ordnance Test Station, Attn: Mr. David M. Nelson, Code P8074, 3202 E. Foothill Blvd., Pasadena 8, Calif.
- (d) Theoretical; applied research.
- (e) The Douglas Aircraft Company computer programs for the solution of the potential flow about bodies of revolution, where the bodies are represented by a surface source density, are being used to theoretically determine hydrodynamic coefficients for bodies of revolution. A comparison between the theoretical values and the experimental values for blunt base bodies will be made first. Depending on the success of the method for these blunt base bodies, the method will then be applied to streamlined bodies having thick boundary layers on the aft end. This will be done by a combination of boundary layer calculations and potential flow calculations to obtain, if possible, a reasonable theoretical model of the flow about such bodies.

U. S. DEPT. OF THE NAVY, OFFICE OF NAVAL RESEARCH.

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TENNESSEE VALLEY AUTHORITY, Engineering Laboratory.

Inquiries concerning the following projects should be addressed to Mr. Rex A. Elder, Director, TVA Engineering Laboratory, P. O. Box 37, Norris, Tenn.

(3629) LOW POWER VHF RADIO GAGES FOR REPORTING RAINFALL AND STREAM LEVEL DATA.	
(d) Development.	
(e) Transistorized radio components powered from nickel cadmium batteries, which will be charged by thermoelectric generators and/or solar cells, will be used. Data in gray code will be transmitted by audio tone pulses. Unattended operation of long duration is a primary objective in the design of these stations.	
(g) The complete data chain has been assembled and tested.	
(4441) MEASUREMENT OF KAPLAN TURBINE DISCHARGES USING OTT COMPONENT CURRENT METERS.	
(d) Equipment development and field measurement operation.	
(e) Turbine discharge rating equipment, using the Ott component type current meters, has been developed to measure the discharge of turbine units. Twenty-seven current meters mounted on three frames are used to simultaneously measure velocities in the three intakes of each unit by either the step or integration method. Measurements made at several fixed loads are employed to calibrate the Winter-Kennedy scroll case pressure taps. The Winter-Kennedy taps are used with suitable measuring equipment to determine the discharge for any turbine loading.	
(g) Equipment and measuring techniques have been developed. Measurements of turbine discharge have been completed at eighteen turbine units. Calculation of the turbine discharge based on the field measurements is accomplished using an LGP-30 computer.	
(4878) PARADISE STEAM PLANT, AIR DUCT STUDIES.	
(d) Field investigations for operations.	
(e) Field measurements were taken of the velocity distribution at the entrance to one of the prototype air preheaters	

- at the Paradise project. These measurements were obtained to help determine whether poor velocity distribution contributed to the air preheater tube plugging problems.
- (f) Completed.
 - (g) The velocity distribution was found to be fair to good and not a substantial factor in causing the plugging in the preheaters.
 - (h) Internal report issued.
- (4880) VIBRATION STUDIES OF STEAM PLANT AIR AND GAS DUCTS.
- (d) Experimental; for basic and applied research.
 - (e) Studies are being made to extend our knowledge relating to flow induced duct vibrations and to apply the findings to present and future installations. Duct vibrations which are believed to stem from the highly turbulent flows created by the forced draft fans and by the various duct configurations have been experienced in the duct work of some plants. These turbulent conditions create pressure fluctuations which could lead to wall vibrations.
 - (f) Suspended.
- (4881) BASIC STREAM AND RESERVOIR HEAT BUDGET STUDIES.
- (d) Experimental; for basic and applied research.
 - (e) This is a study to develop the basic temperature prediction equations for a stream or reservoir into which a volume of water at a different temperature is injected. All known variables such as stream flow characteristics, meteorological conditions and thermal characteristics will be included. Theoretical studies, field tests, and possible laboratory studies will be combined to produce verified equations. Additional field data were collected during the year and the measured water temperatures are being compared to the predictions produced by the basic heat budget equation.
 - (g) A basic heat budget equation has been developed which relates mean water temperature to meteorological, hydraulic, and thermal characteristics. The equation can be used to predict mean water temperature as a function of distance below a steam plant, using 24-hour time averages. To date this equation has been proved for the completely mixed non-recirculating river flow case.
- (5004) NICKAJACK PROJECT.
- (d) Experimental; for design.
 - (e) Studies are being conducted on a 1:150 horizontal by 1:90 vertical scale model, representing an area of approximately 2 miles in length by 1 mile in width of the river site. River diversion, necessary for the selected project scheme, is being investigated in relation to associated navigation problems. Hydraulic features connected with various construction phases are also being studied.
 - (h) Five internal reports have been issued to date.
- (5005) WHEELER PROJECT, TURBINE UNITS 9, 10 and 11, VIBRATION STUDIES.
- (d) Field investigations; applied research.
 - (e) Severe vibrations of these fixed-blade turbines has lead to instrumentation of one unit to study the inter-relationships of the hydraulic forces and the unit vibrations. Pressures were measured in the scroll case at 3 locations, on the head cover at one location and at 5 locations in the draft tube. Vibrations were measured at 8 radial points on the shaft and at one vertical point. A measurement was also taken at one point under the generator thrust bearing support bracket.
 - (f) Field measurements and laboratory evaluations completed.
- (g) The vibrations, which were evident in the turbine shaft, are due to the periodic whip of an unstable rope vortex in the draft tube below the runners. Draft tube pressure fluctuations correlated well with the turbine shaft vibration characteristics.
 - (h) Report issued.
- (5007) STUDIES OF BEND LOSSES AND VANING IN LARGE CONDUITS.
- (d) Experimental; basic research and applied research.
 - (e) These studies are to develop basic design criteria for air and gas duct systems for steam plants, with particular reference to methods of vaning for optimum flow conditions and minimum head loss characteristics and to the effects of multiple bends on the loss characteristics of the system. The first phase of these studies will deal with duct sections having height to width ratios of 2:1. Other phases will deal with more complex duct shapes and bends. The data will be developed entirely by laboratory testing. The study is being conducted on a limited basis in 1964 and will be expanded in 1965.
 - (f) Temporarily suspended.
- (5008) STUDIES OF THE EFFECTS OF TURBULENCE ON JET DISPERSION.
- (d) Experimental; basic and applied research.
 - (e) To determine the effect of the turbulence in the discharging jet from a chimney on the rise of the plume above the stack, measurements of the turbulence characteristics of several TVA stacks will be made and by means of model comparisons, the mixing characteristics of the jet will be compared with those for an ideal discharge condition. These data will then be combined by the Division of Health and Safety with other field data from the same plants to develop an overall plume rise equation. This study is co-sponsored by TVA and USPHS. Field and model studies will be conducted during 1964 and 1965.
 - (f) Temporarily suspended.
- (5386) NICKAJACK PROJECT--LOCK MODEL.
- (d) Experimental; for design.
 - (e) A 1:25 scale model of the 800' x 110' main Nickajack lock was used to adapt the multi-port filling and emptying system to this size chamber. The proposed intake and outlet structures for both the main and 600' x 110' auxiliary lock are being tested by incorporating them with the main chamber model and a simplified model of the auxiliary chamber.
- (5387) NICKAJACK PROJECT--VALVE-CULVERT MODEL.
- (d) Experimental; for design.
 - (e) A 1:10 model of an existing lock filling valve, with related culvert appurtenances, is being used to determine the nature and origin of the hydrodynamic forces which act on reversed tainter lock filling valves. The model was specifically designed to reproduce the transient conditions existing while the valve is opening. Two valve designs are being compared with respect to their reaction to hydrodynamic forces.
 - (g) Rarefied air pulled from the bulkhead slot immediately downstream from the filling valves was proven to cause severe pressure pulsations which, in turn, act on the valve.
- (5388) NICKAJACK PROJECT--SPILLWAY MODEL.
- (d) Experimental; for design.
 - (e) Studies were conducted on a 1:35 scale model of three of the ten spillway bays of the Nickajack project. Tests were for the purposes of determining the spillway capacity under the maximum design head, developing the optimum upstream pier shape,

and finding a relatively simple yet effective apron design. Such factors as water surface profiles through a bay and pressures on the piers under adverse gate openings were also investigated.

- (f) Continuing.
- (g) An upstream pier shape with a relatively sharp nose was found to decrease vortex action upstream from the gate for gated discharges. A simple horizontal spillway apron with a dentated end sill minimized scour and produced acceptable wave action.
- (h) Three internal reports have been issued to date.

(5389) FORT LOUDOUN, DOUGLAS AND MELTON HILL PROJECTS--SPILLWAY DISCHARGE RATING TABLES.

- (d) Applied research; operations.
- (e) Booklets containing spillway gate operating instructions, the gate arrangements schedule and the tables of possible spillway discharges were compiled for use at the dams. The final discharges were calculated using the LGP-30 computer.
- (f) Completed.
- (g) Tables issued.

(5390) WIDOWS CREEK STEAM PLANT--CONDENSER WATER INTAKE PROBLEMS--UNITS 7 AND 8.

- (d) Experimental; applied research.
- (e) Tests were conducted using a 1:40 scale model of the Widows Creek Plant, Unit 7 and 8, condenser water intake problems. Both surface currents and sub-surface currents were reproduced in their relation to the condenser water intakes. The model study was performed to develop entrance conditions which would improve the operations of the intake.
- (f) Completed.
- (g) By simulating the flow patterns in the area of the condenser water intake, changes in the prototype entrance conditions were developed which would provide for improved flows into the intake.
- (h) Advance report in process.

(5391) WIDOWS CREEK STEAM PLANT--UNIT NO. 8--FLOW NOZZLE RATING.

- (d) Applied research; operations.
- (e) The 16-inch flow nozzle for the condensate discharge line in Unit 8 at Widows Creek Plant was rated in the Laboratory's rating equipment. Coefficients of discharge were determined for the Reynold's Numbers range between 4.8×10^5 and 3.4×10^6 which takes in the complete operating range for this generating unit.
- (f) Completed.
- (h) Rating table issued.

(5392) MODEL FLUME TO BE USED TO STUDY THERMAL DENSITY RECIRCULATION PROBLEMS.

- (d) Experimental; operations and basic research.
- (e) A model flume was constructed of transparent material and equipped with circulating pumps to simulate a typical steam power plant's condensate intake and outlet system. The flume is approximately 100 feet in length and 9 inches deep by 12 inches wide. The basic intent is to develop and prove the analytical equations for flows in the vicinity of a steam plant or in similar areas.

TENNESSEE VALLEY AUTHORITY, Hydraulic Data Branch.

Inquiries concerning projects should be addressed to Mr. James W. Beverage, Chief, Hydraulic Data Branch, Tennessee Valley Authority, Knoxville, Tenn. 37902.

(765) EVAPORATION IN THE TENNESSEE BASIN.

- (d) Field investigation; applied research.
- (e) To provide data for estimating reservoir losses and derive a general rule, applica-

ble to the Basin, permitting computation of evaporation from pans at six locations in Basin, together with standard meteorological readings.

- (h) Results published in monthly and annual bulletins, "Precipitation in Tennessee River Basin" (Project 768).

(768) PRECIPITATION IN TENNESSEE RIVER BASIN.

- (d) Field investigation; basic research.
- (e) A comprehensive study of rainfall and other weather phenomena for purposes of water dispatching and improvements in water control; storm studies as related to maximum precipitation, rainfall-runoff, spillway design and operation, etc.
- (h) Monthly and annual bulletins, "Precipitation in Tennessee River Basin."

(769) RESERVOIR AND STREAM TEMPERATURES.

- (d) Field investigation; basic research.
- (e) Study of water utilization and water movement as concerns industrial plant locations and stream pollution. Variations in temperature from surface to bottom in reservoirs throughout the year are determined by soundings, and by continuous recording gages in natural streams.

(771) GALLERY DRAINAGE IN LARGE DAMS.

- (d) Field investigations; design.
- (e) Weirs are placed in main galleries and drainage measured as check on tightness and stability.

(779) MAXIMUM POSSIBLE PRECIPITATION IN TENNESSEE VALLEY.

- (b) Cooperative with U. S. Weather Bureau.
- (d) Theoretical; applied research.
- (e) Hydrometeorological analysis of large storms with upward adjustments of controlling factors to maximum limits as applied to the Tennessee Valley and subdivisions.
- (g) Results to be published as one of current series of hydrometeorological reports by the U.S.W.B. and cooperating agencies.

(780) PERIODIC EVALUATION OF GROUND-WATER STORAGE.

- (d) Theoretical; operation.
- (e) By analysis of current records of stream discharge, the volumes of runoff in ground-water and channel storage are determined for use in operation of multi-purpose reservoirs.
- (g) Results reported monthly and weekly within the organization.

(785) SEDIMENTATION OF EXISTING RESERVOIRS.

- (d) Field investigation; basic research.
- (e) Selected ranges in reservoirs are probed and sounded, volumetric samples are collected and analyzed, quantity and distribution of sediment are computed to determine deposition by stream, probable life of reservoir, effect of sediment storage on navigation channels and sedimentation of down-stream reservoirs, and probable sedimentation in future reservoirs.

(3306) COOPERATIVE RESEARCH PROJECT IN WESTERN NORTH CAROLINA.

- (b) Project conducted in cooperation with North Carolina State College of Agriculture and Engineering.
- (d) To determine water-land relationships for some of the principal soils used for agricultural purposes in western North Carolina under important vegetative covers. Observations include rainfall, runoff, soil-moisture, potential evapotranspiration, and actual evapotranspiration.
- (e) A statistically designed rotation of four covers on four small watersheds and a separate evaluation of deep-rooted crop on a

- fifth watershed.
- (f) Field studies of the deep-rooted crop, alfalfa, have been discontinued.
 - (g) Results to date are summarized in annual reports on the project.
 - (h) "Watershed Project," Research and Farming, Vol. XXII No. 4, Spring 1964, N. C. Agricultural Experiment Station.
- (3307) PARKER BRANCH PILOT WATERSHED RESEARCH PROJECT.
- (b) Project conducted in cooperation with North Carolina State College of Agriculture and Engineering.
 - (d) To determine the effects upon the hydrology of the watershed of an intensive farm development program designed to give the optimum economic well-being of the people using the land. Rainfall, runoff, suspended and deposited sediment are observed, periodic soils-land-use and inventories are made and records of income summaries and public and private investments are maintained.
 - (e) Project activities are divided into calibration, action, and evaluation phases.
 - (f) Agricultural economics portion of project terminated June 30, 1962; hydrologic portion terminated September 30, 1962.
 - (g) Results are summarized in annual reports on the project.
 - (h) "Parker Branch - An Experiment in Appalachian Agriculture 1953-62." "The Story of Parker Branch," a 30-minute 16 mm sound and color motion picture.
- (3308) WHITE HOLLOW WATERSHED.
- (d) To study the effect of changes in the vegetal cover on a watershed taken out of cultivation on the hydrologic factors of runoff and soil erosion.
 - (e) Continuous record from 1935 of rainfall, runoff, and suspended sediment, and periodic determination of vegetal cover indexes.
 - (f) Trees have been marked for selective cutting which will be accomplished in the near future.
 - (g) During the 24-year period 1935-1958, the forest cover improvement in the watershed resulted in greater watershed protection with no measurable change in water yield, no change in volume of either surface runoff or ground-water runoff, marked reduction in summer peak rates of discharge with lesser reduction in winter rates, a prolongation of the period of draining of surface runoff from the channel system, and a 96 percent reduction in the sediment load.
- (3309) PINE TREE BRANCH WATERSHED.
- (d) To determine the effects upon the hydrology of the watershed by reforestation and erosion control measures.
 - (e) Continuous record from 1941 of rainfall, runoff, ground water, and sediment loads.
 - (f) Trees have been marked for selective cutting which will be accomplished in the near future.
 - (g) During the 20-year period 1941-1960, the cover improvement and erosion control in the watershed resulted in a decrease in surface runoff volumes and an increase in ground-water discharges, marked reductions in summer and winter peak flood discharges, a reduction in overland surface velocities, a prolongation of the period of draining of surface runoff from the channel system, an appreciable decrease in water yield, and a 96 percent reduction in sediment load.
- (4011) NORTH FORK CITICO CREEK RESEARCH WATERSHED.
- (b) Project conducted in cooperation with U.S. Forest Service.
 - (d) Field investigation; basic research.
 - (e) To determine the effects of normal, high-standard National Forest Multiple-use management upon the hydrology of the area. Observations include rainfall, runoff, air and water temperature, and humidity.
- Timber inventories, soil surveys, wildlife inventories, and evaluations of soil disturbances will be made. Project activities are divided into calibration, development, and evaluation phases.
- (g) Results are published in annual reports distributed to cooperating agencies.
 - (h) "North Fork of Citico Creek," Cooperative Watershed Study, Tennessee Valley Authority, U. S. Forest Service, Tennessee Game and Fish Commission, 1963.
- (4884) UPPER BEAR CREEK EXPERIMENTAL PROJECT.
- (b) TVA Tributary Area Development project cooperative with U. S. Forest Service and Auburn University.
 - (d) Quantitative determination of the effect of soil type, slope, and vegetative cover upon runoff, peak discharge, and erosion on small watersheds progressing to large watersheds. Development of procedures to make data usable in projecting effects from small watersheds to larger drainage areas and to transfer results of the study to ungaged areas.
 - (e) Four general types of land cover and use will be considered in the study of the watersheds that progress downstream from areas of several hundred acres through intermediate-sized watersheds to a drainage area of 143 square miles.
 - (f) The instrumentation phase of the project was completed in 1964.
 - (g) Results will be published in annual reports.
-
- U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION,
CORPS OF ENGINEERS.
- Inquiries concerning the following projects should be addressed to the Director, U. S. Army Engineer Waterways Experiment Station, Corps of Engineers, P. O. Box 631, Vicksburg, Miss. 39181.
- (236) MISSISSIPPI BASIN MODEL.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D. C.
 - (d) Experimental; for design.
 - (e) The project provides for construction and operation of a model of the Mississippi River watershed including the Missouri, Ohio, White, Arkansas, and Red Rivers and their principal tributaries. The model area comprises 200 acres and reproduces 1,250,000 square miles of the Mississippi Basin. The topography of the streams and flood plains is reproduced to a horizontal scale of 1:2,000 and vertical scale of 1:100. All existing and proposed flood-control reservoirs, levees, dikes, floodwalls, and other pertinent works are reproduced. The completed construction consists of the Upper Mississippi from Hannibal, Missouri, to Baton Rouge, Louisiana; the Missouri River from Sioux City, Iowa, to the mouth; the Ohio River from Louisville, Kentucky, to the mouth including the Wabash River below Riverton, Indiana; the Tennessee River from Pickwick Dam, Tennessee, to the mouth; the Cumberland River from Old Hickory Dam, Tennessee, to the mouth; the White River from Georgetown, Arkansas, to the mouth; the Arkansas River from Blackburn Dam site, Oklahoma, to the mouth; and the Red River from Alexandria, Louisiana, to the mouth. Water-surface elevations are measured by electrically operated stage devices with the recorders located in central control buildings. Streamflow is introduced and controlled by automatic instruments called inflow controllers. The model was designed to study coordination of releases from reservoirs, investigate the effect of reservoir operation on flood stages, check the routing of project and other floods, establish and check levee grades, predict stages, and determine the effect of floodways on stage reduction.

- (g) The extent of model operation each year is determined by the testing programs directed by the Mississippi Basin Model Board and Chief of Engineers and requested by Divisions and Districts that have operable sections on the model. The model was operated as an integrated unit to Memphis, Tennessee, for comprehensive (basinwide) tests. Tests were conducted of the four historical floods-- 1937, 1943, 1945, and 1950--using those reservoirs (EN) scheduled for completion in the near future (approximately 1970), and with ultimate reservoir (END) modification assuming sufficient capacity in both groups of reservoirs to store all inflows that would contribute to flooding on the Lower Mississippi River, and with EN and END reservoirs operated to full capacity to store inflows that affect crest stages of Lower Mississippi River. Tests were completed of the 1927 flood from St. Louis, Missouri, and Golconda, Illinois, to Memphis, Tennessee, using the actual flood with present-day conditions and modification by the EN and END reservoirs. Tests were conducted to verify the model between Memphis, Tennessee, and Baton Rouge, Louisiana, to the 1945, 1950 and 1961 floods. Tests were conducted for the U. S. Army Engineer Division, Missouri River, to assist in the design of the Missouri River Agricultural Levees from Kansas City to the mouth. Tests of the 1937 and 1950 floods on the Tennessee and Cumberland Rivers with the canal connecting Barkley and Kentucky Reservoirs open, and tests of the 1927, 1946, and hypothetical flood and steady-flow tests of the Cumberland River were conducted for the Nashville District.
- (425) COMPREHENSIVE MODEL STUDY, DELAWARE RIVER, PENNSYLVANIA.
- (b) District Engineer, U. S. Army Engineer District, Philadelphia, Corps of Engineers, Philadelphia, Pa.
- (d) Experimental; for design.
- (e) To develop and test plans for reduction of shoaling in several ranges of the navigation channel, and to determine the probable effect on the hydraulic and salinity regimen in the estuary that would result from modifications of channel depth and alignment and flow regulation, the entire Delaware River estuary from the Atlantic Ocean to Trenton is reproduced in a fixed-bed, silt-injection type model with scale ratios of 1:1,000 horizontally and 1:100 vertically. Tides and tidal currents are reproduced by automatic tide generators. Observed prototype salinities are reproduced in the Delaware Bay portion of the model, and provisions made for the injection of silt, and for measuring silt deposits. Studies are also made of salinity intrusion and the dispersion and dilution of wastes discharged into the estuary.
- (g) Tests to determine the effects of various degrees of rehabilitation and destruction of Reedy Island and Pea Patch Island training dikes on hydraulic conditions throughout the reach affected revealed that rehabilitation would not benefit navigation or decrease maintenance dredging. Pennsville dike, completed in 1943 to an elevation of +8.0 feet, has also deteriorated and is presently being restored to +3.0 feet. Tests to determine the benefits of raising this dike an additional 5 feet revealed that the crest elevation of +3.0 feet would be satisfactory.
- (h) "Delaware River Model Study"; Report 4, "Dike Rehabilitation; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-337, May 1964. (Available on loan.)
- (993) CAVITATION RESEARCH.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; applied research.
- (e) The cavitation characteristics of such elements as baffle piers, steps in stilling basins, spillway and conduit gate slots, and offset joints are studied in either a vacuum tank or a variable-pressure, closed-jet water tunnel. The investigation includes a review of literature to evaluate the many variables that affect cavitation results. A high-velocity water facility is being used to study resistance of concrete and protective coatings to cavitation.
- (994) EFFECTS OF MODEL DISTORTION.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; applied research.
- (e) This is a general study to determine the hydraulic effects of various types and degrees of model scale distortion on velocity distribution and other hydraulic conditions, with the ultimate aim of establishing limits of permissible distortion for the various types of models. A rectangular flume having a 90-degree bend with provisions for changing the vertical scale to provide distortions of 0 to 10 is used in the study.
- (f) Suspended.
- (998) WAVE FORCE ON BREAKWATERS.
- (b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.
- (d) Experimental; applied research.
- (e) This is a general investigation to obtain data from which the magnitude and elevation of wave forces on a vertical wall can be predicted. The specific purposes of the study are to (1) study existing literature and testing equipment; (2) verify experimentally the clapotis pressure theory; and (3) determine maximum shock-type pressures, delineate the critical conditions necessary to create the extremely high shock pressures, and determine the magnitude of pressures due to partially breaking waves. Preliminary measurement of wave-pressure distribution on a vertical wall resulting from breaking waves, conducted in a 1.0- by 1.5- by 94-foot wave flume was completed, and preparation of a report on this phase of the investigation was begun. A theory for the formation of short pressures on vertical walls due to breaking waves was developed, and plans were in preparation for special tests to investigate the applicability of the new theory.
- (999) STABILITY OF RUBBLE-MOUND BREAKWATERS.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; applied research.
- (e) Rubble-mound structures are studied in a 5- by 4- by 119-foot and 12.5- by 4- by 119-foot wave flumes to develop design procedures and formulas, supported by experimental data, from which the design of safe and economical breakwaters can be determined. In addition to quarrrystone, tetrapods, tetrahedrons, tribars, quadripods, modified cubes, and other specially molded armor units are being studied. A 50- by 5.5- by 250-foot, L-shaped wave flume designed to allow the testing of breakwater sections using various angles of wave incidence will also be used in this study.
- (1002) EFFECTS OF SCALE AND OPERATING TECHNIQUES ON HARBOR WAVE ACTION AND BREAKWATER MODELS.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; applied research.
- (e) Tests are conducted in flumes and harbor model basins to obtain information that will allow more accurate determination of optimum scales for wave models, and the effects of different scales and operating techniques on the accuracy of model results.
- (f) Inactive.

(1004) INSTRUMENTATION.

- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; development.
- (e) Various types of measurement and control equipment for use in hydraulic studies are being developed. A feasibility study for a portable salinity meter for model use, and a pilot study for a turbulence meter were completed. Development of improvements for remote-control system for a model towboat was suspended. Development of improvements for hawser-stress transducer for measuring hawser forces acting on tows in model locks and the development of a revolution-sensing and remote-indicating device for velocity meters were continued. The development of a spherical-head turbulence meter, a water-level indicator for tests of prototype locks, and improvements of a current-direction indicator were undertaken.

(1467) DEVELOPMENT OF HYDRAULIC DESIGN CRITERIA.

- (b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.
- (d) Analytical (model and prototype); for design.
- (e) A general study to develop, analyze, and disseminate to Army Corps of Engineers establishments hydraulic design criteria to ensure adequate capacity, economy of design and construction, and safe and satisfactory operation of large hydraulic structures. Criteria are developed from model and prototype tests relating to the design of spillways, outlet works, gates and valves, channels, and navigation structures.
- (g) Theoretical development of procedures for determining flow patterns in spillway buckets by electronic computer programs was continued. University of Iowa laboratory data on boundary layer development on steep slopes were analyzed using the new concept of energy thickness. The results of this analysis was combined with limited prototype data to produce design criteria charts and a procedure for evaluating spillway energy losses occurring during development of the turbulent boundary layer. The procedure relates the boundary layer thickness, the displacement thickness, and the energy thickness with the boundary length and surface roughness.
- (h) "An Investigation of Spillway Bucket and Toe Curve Pressures" and "A Study of Spillway Energy Losses During Development of the Turbulent Boundary Layer." U. S. Army Engineer Waterways Experiment Station Miscellaneous Papers Nos. 2-625 and 2-642, February and April 1964, respectively. (Available on loan.)

(1474) OPERATING FORCES OF MITER-TYPE LOCK GATES.

- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; applied research.
- (e) A general study to collect basic data on operating forces of miter-type lock gates and to determine the effect of various elements upon these forces was conducted in a 1:20 model. A lock chamber 110 feet wide was reproduced with provisions for varying the length up to 600 feet on each side of the gate. Forces required for operation of miter gates were measured for variations of the following elements: gate leaves, speeds and accelerations of operation, submerged depths, recess shapes, bottom clearances, chamber lengths, and nonsynchronous operation of gate leaves.
- (f) Completed.
- (g) Three types of linkages were used in determining the operating forces of miter-type lock gates: The Panama Canal, the Ohio River, and the modified Ohio River linkages. In all tests, the maximum recorded torque occurred as the gates entered the mitered position in the closing cycle. The Ohio

River linkage developed torques greater than did the other two linkages. The maximum torques of the modified Ohio and Panama linkages were practically equal which seems logical since both linkages have no angularity between strut and sector arms in the mitered position. In all tests, the recorded torques decreased as the submergence was lowered by 1/2-foot increments from 4.0 feet to 1.0 foot in the models. The recorded torques decreased as the time of operation was increased in increments of 6.7 seconds from 10.1 and 13.4 seconds to 40.2 seconds. The effect of chamber length for the modified Ohio River linkage was determined by varying the model length from 15 to 30 feet in 5-foot increments. In general the torque decreases as the chamber is lengthened. In model tests the effect of wave action upon torque was negligible except for the 30-foot chamber where waves of small amplitude but great length caused torques equal to or greater than those recorded as the gates entered the mitered position. Barges simulating a 9-foot draft were installed at 25, 50, 75, and 100 feet below the gates in the 600-foot chamber of the modified Ohio River linkage. The barges aided in reducing wave action and torques as the gates entered the mitered position.

- (h) "Operating Forces on Miter-Type Lock Gates." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-651, June 1964. (Available on loan.)

(1475) SIPHON ACTION AT PUMPING PLANTS.

- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; applied research.
- (e) This study was conducted to aid in developing design criteria for pumping plants that depend on development of siphonic action in the discharge side of the pumps in order to yield the required discharge. Full-size models of a 6-inch and 12-inch plastic discharge line were tested. Variables investigated during the tests were: initial rates of flow, tailwater levels, slope and length of the riverward leg, and venting conditions at the crown.
- (f) Final report in preparation.

(1986) SALT WATER INTRUSION AND RELATED PHENOMENA.

- (b) Committee on Tidal Hydraulics, Corps of Engineers (correspondence should be addressed to Mr. J.B. Tiffany, Chairman, Committee on Tidal Hydraulics, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.).
- (d) Experimental; applied research.
- (e) Analyses of prototype data, flume tests, and analytical studies to establish fundamental laws describing the phenomena involved are being performed to determine the effects of the physical and hydraulic features of estuaries such as tidal prism, tidal range, freshwater discharge, channel depth, channel width, etc., on the extent of salinity intrusion, the nature of salinity intrusion, the magnitudes and durations of current velocities, and other factors considered essential to proper solution of estuarine problems encountered by the Corps of Engineers. The flume studies are made in a lucite flume 327 feet long, 1.5 feet deep, and 0.75 foot wide. One end of the flume is connected to a 25-foot-square tidal basin in which any desired tide can be produced and in which the salinity can be controlled. The opposite end is connected to a freshwater source. Combinations of flume roughness, tidal range, tidal period, source salinity, mean depth, and freshwater inflow are studied.

(1987) RIPRAP PROTECTION AT HYDRAULIC STRUCTURES.

- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.

- (d) Experimental; applied research.
- (e) The study of erosion characteristics of various sizes of riprap and gravel material is being performed with a view to securing adequate protection at minimum cost. Measurements of velocity and depth at which movement of material begins will be made. Data collected on models of specific structures are being analyzed in an effort to generalize the test results.
- (1986) WATER TEMPERATURE EFFECTS ON BED FORMS AND ROUGHNESS.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; applied research.
- (e) A laboratory flume, in which water temperatures can be varied to simulate normally experienced summer and winter temperatures, is being used to investigate the effects of water temperature on streambed forms and roughness of various types of bed materials. Preliminary tests with fine sand have been completed and tests with crushed coal undertaken.
- (f) Suspended.
- (2428) MODEL STUDY OF SAVANNAH HARBOR, GEORGIA.
- (b) District Engineer, U. S. Army Engineer District, Savannah, Corps of Engineers, Savannah, Georgia.
- (d) Experimental; for design.
- (e) The investigation was conducted in a model which reproduced the following: 1) that portion of the Atlantic Ocean, adjacent to the harbor entrance, from Calibogue Sound on the north to Wassaw Sound on the south; 2) the Savannah River and its flood plain to the head of tide at Ebenezer Landing; and 3) that portion of the Intracoastal Waterway which crosses the area included in the model. The model was of fixed-bed construction with scale ratios, model to prototype, of 1:800 horizontally and 1:80 vertically. Automatic tide generators were used to reproduce tides and tidal currents throughout the harbor, and salt water was used in the model ocean to reproduce the effects of density difference on current velocities and distributions. Shoaling studies were made by injecting finely ground gilsonite into the model to reproduce the patterns of shoaling as observed in the prototype, following which the effects of proposed improvement plans on shoaling patterns were observed and evaluated. Studies were also made of the effects of proposed improvement plans on dispersion and dilution of contaminants discharged into the harbor. Refinements of plans for reducing and localizing shoaling were tested for conditions of recently recommended changes in project channel width and depth.
- (f) Tests completed; preparation of Section 5 of final report in progress.
- (g) Model tests indicated that pollution of Wilmington River by City of Savannah municipal and industrial wastes could be reduced by closure of south channel and/or St. Augustine Creek. Tests also indicated that bank erosion in north channel will probably be reduced by construction of the recommended deeper and wider channel.
- (h) "Savannah Harbor Investigation and Model Study," Volume III, "Results of Model Investigations"; Section 4, "Results of Tests of Increased Channel Dimensions." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-580, in publication. (Available on loan.)
- (2673) MODEL STUDIES OF BARKLEY LOCK AND DAM, CUMBERLAND RIVER, TENNESSEE.
- (b) District Engineer, U.S. Army Engineer District, Nashville, Corps of Engineers, Nashville, Tennessee.
- (d) Experimental; for design.
- (e) A 1:120 model, reproducing the Cumberland River from mile 29.4 to 32.2, the lock, dam, and powerhouse, was used to investigate flow characteristics in the approaches to the lock. A 1:36 model, reproducing the riverward downstream lock wall including the culvert manifold which discharges into the spillway stilling basin, five spillway bays, 324 feet of approach channel, and 596 feet of exit channel, was used to investigate flow characteristics in the stilling basin and exit channel. The emergency lock gate was studied in a 1:25 model which reproduced the gate, gate sill, and portions of the upstream lock approach and the lock chamber downstream from the gate. This model was used to determine: 1) hydraulic forces on and stability of the emergency gate under various flows including free flow over the lock miter sill; 2) hydrostatic forces on the gate in various positions; 3) gate wheel reactions and sill roller reactions at given positions; and 4) head loss through the bridge decking.
- (h) Final report in preparation.
- (2678) MODEL STUDY OF NAVIGATION CONDITIONS, MCALPINE LOCKS AND DAM, OHIO RIVER.
- (b) District Engineer, U. S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.
- (d) Experimental; for design.
- (e) A fixed-bed, 1:120 model reproduced a six-mile reach of the Ohio River including adjacent overbank areas, the locks and dam structures, and all bridges and other structures that might affect flow conditions. Purposes of the model study were to: determine the effects of location, size, and alignment of the dam on stages and currents in the upper pool; determine the effects of location, size, and alignment of a new approach channel on navigation and surge conditions; determine the best location for a new navigable span on the Pennsylvania Railroad bridge; determine a method of operating the dam for optimum navigation conditions; study navigation conditions in the lower approach as affected by flow through dam, powerhouse, and lock-emptying system; and provide a means for navigation interests to satisfy themselves as to the acceptability of the proposed plan by observing the model in operation.
- (h) Final report in preparation.
- (2680) MODEL STUDY OF HURRICANE TIDES IN NARRAGANSETT BAY, RHODE ISLAND.
- (b) Division Engineer, U. S. Army Engineer Division, New England, Corps of Engineers, Boston, Massachusetts.
- (d) Experimental; for design.
- (e) A fixed-bed model, 1:1,000 horizontally and 1:100 vertically, reproduces all of Narragansett Bay and an adjacent portion of the Atlantic Ocean. An automatic tide generator reproduces normal tides throughout the model, and a separate, manually operated generator reproduces hurricane tides of the desired characteristics at the bay entrance. Numerous barrier plans for prevention of hurricane-tide damage have been proposed. The relative and absolute effectiveness of these plans in reducing hurricane-tide elevations throughout the bay system were determined and the effects of the best plan on such important factors as tidal circulation, pollution, salinity, and shoaling for normal conditions were investigated. Fresh water only is used in the model during tests of the proposed barrier plans, but both salt and fresh water are used in tests to determine the effects of barrier plans on all significant factors for normal conditions. Model appurtenances consist of automatic tide gages to record both hurricane-tide and normal-tide elevations at critical points, recording salinity meters, recording dye meters for observing pollution and/or flushing characteristics, current velocity meters,

- and equipment for simulating shoaling of the channels and other navigation facilities.
- (f) Completed.
- (g) Model tests indicated that barriers should not be located in the central portions of the bay because of excessive buildup of surge heights downstream from such barriers; that a lower bay barrier alone could not satisfy the requirements of the Navy and at the same time afford the desired reductions in surge heights at upstream locations, but that the combination of a gated structure at Fox Point for the protection of Providence with a system of lower bay barriers with ungated openings could satisfy the requirements of the Navy for maximum current velocities and at the same time provide hurricane-surge protection throughout the bay system. However, the current velocities and patterns in the ungated navigation openings would not be safe for navigation by all craft which use Narragansett Bay. The recommended barrier scheme includes a battery of gated openings as well as the ungated navigation openings in both the East and West Passage barriers. The addition of these gated openings should provide a satisfactory solution to the velocity problem. The recommended plan, if authorized for construction, will be tested to determine the exact effects on the salinity regimen of the bay on the rates and patterns of diffusion and flushing of wastes, and on shoaling of the navigation channels.
- (h) "Protection of Narragansett Bay from Hurricane Surges, Summary Report; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-662, October 1964. (Available on loan.)
- (2681) SCALE-EFFECT TESTS OF RUBBLE-MOUND BREAKWATERS.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
- (d) Experimental; applied research.
- (e) Tests are being conducted by the Coastal Engineering Research Center, under the supervision of the Waterways Experiment Station, to investigate the effects of model scale on the results of experimentally determined criteria for the design of rubble-mound breakwaters. Stability tests have been made of a breakwater slope of 1 on 1-1/2 using wave periods of 2.61, 3.75, 7.87, and 11.33 seconds. Tests in the Coastal Engineering Research Center wave flume (15 feet by 20 feet by 635 feet) using a linear scale of 7.5 to 1 based on the tests conducted in the Waterways Experiment Station 5- by 4- by 119-foot wave flume were temporarily suspended. Stability tests have also been conducted in the Waterways Experiment Station small wave flume (1 foot by 1.5 feet by 94 feet) using a scale of 0.5 to 1 based on tests conducted in the 5- by 4- by 119-foot wave flume. Therefore, data on the stability of rubble-mound breakwaters will be available for three different linear scales, 0.5 to 1, 1 to 1, and 7.5 to 1. Test data from the Coastal Engineering Research Center wave flume will be correlated with data from the Waterways Experiment Station flumes. Testing of 75-pound quadripods in the Coastal Engineering Research Center's large wave flume was completed. Analysis of data was in progress.
- (2-31) MODEL STUDY OF SOUTHWEST PASS, MISSISSIPPI RIVER.
- (b) District Engineer, U. S. Army Engineer District, New Orleans, Corps of Engineers, New Orleans, Louisiana.
- (d) Experimental; for design.
- (e) To determine the effectiveness of proposed improvement works (jetty extensions, channel realignments, and contraction works) in eliminating or reducing the periodic maintenance now required in order for deep-draft vessels to navigate the jetty and bar channels of Southwest Pass, the lower 12 miles of the Pass and the adjacent area of the Gulf of Mexico were reproduced in a fixed-bed model to scale ratios of 1:500 horizontally and 1:100 vertically. Tides, tidal currents, littoral currents, and wave action in the Gulf of Mexico, and saltwater and freshwater flows in Southwest Pass and the bar channel were reproduced in the model. Shoaling studies were made by introducing various mixtures of plastic materials into the model to simulate prototype shoaling materials and thus reproduce in the model the patterns and distribution of shoaling that occur in the prototype.
- (h) Final report in preparation.
- (2932) MODEL STUDY OF SHOALING, HUDSON RIVER, N. Y.
- (b) District Engineer, U. S. Army Engineer District, New York, Corps of Engineers, New York, N. Y.
- (d) Experimental; for design.
- (e) A comprehensive, fixed-bed model, constructed to linear scales of 1:100 vertically and 1:1,000 horizontally, is being used to determine the source of material shoaling the Hudson River in the vicinity of Edgewater and Weehawken piers and the most effective means of reducing or eliminating this shoaling. The model reproduces Upper and Lower New York Bays, Raritan Bay, Hudson River to Hyde Park, East River to Throgs Neck, and tributaries flowing into the modeled bodies of water. Provisions are included for reproducing tides, freshwater discharge, salinity intrusion, and shoaling. Another model, reproducing the Hudson River between pier 21 (Duane Street) and West 158th Street, Manhattan, to scales of 1:100 vertically and 1:300 horizontally, and including provisions for simulating tides, tidal currents, and shoaling of navigation slips is being used to determine the causes of shoaling in the pier slips in New York Harbor, and to develop plans for alleviating this shoaling.
- (h) Tests completed; final report in preparation.
- (3236) MODEL STUDY OF MAXWELL LOCKS AND DAM, MONONGAHELA RIVER, PENNSYLVANIA.
- (b) District Engineer, U. S. Army Engineer Dist., Pittsburgh, Corps of Engineers, Pittsburgh, Pennsylvania.
- (d) Experimental; for design.
- (e) A 1:120 fixed-bed type, comprehensive model, reproducing about 2.5 miles of the Monongahela River and the locks and dam structures, was used to study approach conditions under various river flows and methods of operation of control gates; to determine effects of design modifications; to develop modifications required to overcome any undesirable conditions; and to demonstrate to navigation interests the acceptability of the proposed design from a navigation standpoint.
- (f) Completed.
- (g) Tests indicated that modification of the left abutment of the dam and the left bank improved current alignment along the left side of the channel and reduced velocities in the lower lock approach. Modification of the right bank downstream of the lower guide wall provided additional maneuver area without appreciably affecting navigation conditions. Tests indicated the maximum discharges which could be passed without overtopping the cofferdams during various phases of construction, velocities with the cofferdams in place, and the effects of the cofferdams on navigation during construction.
- (h) "Navigation Conditions at Maxwell Locks and Dam, Monongahela River; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-672, in publication. (Available on loan.)

- (3243) MODEL STUDY OF LOCKS AND DAM NO. 4, MONONGAHELA RIVER.
- (b) District Engineer, U.S. Army Engineer District, Pittsburgh, Corps of Engineers, Pittsburgh, Pennsylvania.
 - (d) Experimental; for design.
 - (e) A 1:120 fixed-bed, comprehensive model, reproducing about 2.5 miles of the Monongahela River and the locks and dam structures was used to determine the effects of modifications to the existing locks and dam on navigation conditions, and to develop modifications required to overcome any undesirable conditions.
 - (h) Final report in preparation.
- (3584) MODEL STUDIES OF RED ROCK DAM, DES MOINES RIVER, IOWA.
- (b) District Engineer, U. S. Army Engineer District, Rock Island, Corps of Engineers, Rock Island, Illinois.
 - (d) Experimental; for design.
 - (e) A 1:50 model that reproduced 900 feet of the approach channel above the spillway, an 825-foot-wide section along the dam, the spillway, conduits, stilling basin, and 575 feet of the outlet channel, and a 1:16 model that reproduced one conduit and a 16-foot-wide portion of the spillway and stilling basin were used to study flow conditions in the approach, particularly at the abutments, to verify stilling basin and training wall design, to evaluate reduction in conduit flow during combined operation, to determine the need for armor plate at the outlet portal, and to study the effects of deflectors above the conduit outlet portals.
 - (h) Final report in preparation.
- (3586) MODEL STUDY OF HOPPER DRAGHEAD.
- (b) District Engineer, U.S. Army Engineer District, Philadelphia, Corps of Engineers, Philadelphia, Pennsylvania.
 - (d) Experimental; for design.
 - (e) To develop improved dragheads designed to attain a greater rate of intake of solids when dredging mud and silt mixtures (soft materials) and dredging densely packed, fine sand (hard material), an investigation was conducted in a 60- by 10-foot flume containing various types of bed material. The draghead and suction line, constructed to a scale of 1:6, were connected to a suction pump mounted on a double carriage that provides travel, both longitudinally and transversely, along the top of the flume.
 - (h) Final report in preparation.
- (3590) MODEL STUDY OF EFFECTS OF HURRICANE BARRIER ON NAVIGATION CONDITIONS IN EAST PASSAGE, NARRAGANSETT BAY, RHODE ISLAND.
- (b) Division Engineer, U.S. Army Engineer Division, New England, Corps of Engineers, Waltham, Massachusetts.
 - (d) Experimental; for design.
 - (e) A barrier across East Passage has been proposed to limit the quantity of water entering Narragansett Bay from hurricane surges. A 1:150 model of East Passage was used to examine ship navigation conditions with respect to barrier location and its navigation opening under current, wave, and wind conditions created by astronomical tides and hurricane surges. A self-propelled, radio-controlled, model aircraft carrier, dynamically similar to its prototype, was used in the tests. Two section models, reproducing the barrier to scales of 1:50 and 1:150, were used to determine the effects of approach depth, roughness of the barrier, model scale, and weir design on the discharge characteristics of the navigation opening. In addition, the 1:150-scale, 3-dimensional model was used to determine the discharge characteristics of two weir plans.
 - (h) Final report in preparation.
- (3597) CORRUGATED PIPE ROUGHNESS STUDY.
- (b) Office of the Chief of Engineers, Department of the Army, and Bureau of Public Roads, Department of Commerce, Washington, D.C.
 - (d) Experimental; applied research.
 - (e) This was a general investigation to determine a resistance coefficient and the law of velocity distribution for flow in structural-plate corrugated pipe. A fiber-glass test section reproducing a 5-foot-diameter standard corrugated pipe at a scale of 1:4 was tested in order to obtain additional data on the resistance coefficient and velocity distribution and to correlate model work with full-scale tests. Fiber-glass test sections reproducing a 5-foot-, 10-foot-, and 20-foot-diameter structural-plate pipe at scales of 1:2.2, 1:8, and 1:16, respectively, were tested to determine the effect of relative roughness upon the resistance coefficient and velocity distribution. The hydraulic gradient and the energy loss through 20- to 80-diameter lengths of test section were established by piezometers located at 5-foot intervals. These piezometers were 1/8 inch in diameter, on center of the crests of the corrugations, and four in number around the periphery of the pipe. Velocity traverses were made by means of calibrated pitot tubes at several locations along the test section for determination of the velocity distribution.
 - (h) Final report in preparation.
- (3902) RADIOACTIVE TRACER TESTS OF SEDIMENT, GALVESTON BAY, TEXAS.
- (b) District Engineer, U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.
 - (d) Experimental; field investigation.
 - (e) The movement of sediment in the vicinity of the Galveston Bay Jetty was investigated by use of radioactive gold-impregnated glass. The glass was ground to the particle size of the natural sediment. In the first series of tests, the activated, gold-impregnated glass was deposited at three locations on the north side of the jetty, and the paths of the particles were traced by instruments from a small boat. Readings were procured over a period of about one week. It was expected that the tidal action, littoral current, and wind waves would move the material around the end of the jetty and/or through the jetty. In a second series of tests, the tracer material was deposited at five additional locations north of the north jetty. These locations extended the area under study beyond the end of the jetty. A third series of tests was conducted in which material was placed at three locations outside the south jetty.
 - (h) Final reports in preparation.
- (3903) MODEL STUDY OF TSUNAMIS AT HILO HARBOR, HAWAII.
- (b) District Engineer, U.S. Army Engineer District, Honolulu, Corps of Engineers, Honolulu, Hawaii.
 - (d) Experimental; for design.
 - (e) A comprehensive, fixed-bed model is being used by the U. S. Army Engineer District, Honolulu, to determine the optimum breakwater plan to decrease wave and surge action in the harbor so that troublesome and damaging ship motion at piers 1, 2, and 3 will be alleviated, and to investigate effects of different plans of construction on reduction of damage to the city of Hilo from tsunamis. The model is about 62 feet wide and 92 feet long, with a vertical scale of 1:200 and horizontal scale of 1:600. The model is contoured from 200 feet above to 300 feet below mean lower low water. This model area of 2,286 square feet is comprised of 12- by 12-foot sections with jacked supports to compensate for differential settlement of the foundation. The model area also includes a

1,809-square-foot concrete slab in the wave generator pit. The wave generator is comprised of 8 pneumatic chambers, each being 6 by 8 by 10 feet. A programmer operates the generator to simulate tsunami waves.

- (g) (1) Fairly good model similitude was obtained. The prototype tsunami data of water heights at key locations, limits of runup, and marigrams were duplicated with reasonable success in the model. (2) Theoretical analyses concerning the behavior of the reflected wave off the high cliffs along the Hamakua Coast were verified in the model. The tests indicated that a large percentage of the destruction caused by the 1946 and 1960 tsunamis was the direct result of this reflected wave. (3) It was decided to adopt the 1946 and 1960 tsunamis as the design waves for barrier tests. Testing to achieve duplication of these waves met with fairly good results. The 1946 tsunami was satisfactorily recorded and preliminary tests for the 1960 tsunami indicated favorable results. (4) Preliminary barrier plans were tested, using the design waves obtained. These tests indicated two or three barrier plans that might solve the tsunami problem in Hilo Harbor. These tests indicated that it was highly possible that the breakwater alignment and crest elevations could be determined in the existing model, thereby eliminating the necessity of going into Phase II of the project.

(3906) POWER PLANT TRANSIENTS TESTS, GARRISON AND OAHE DAMS, MISSOURI RIVER, NORTH DAKOTA.

- (b) Division Engineer, U.S. Army Engineer Division, Missouri River, and District Engineer, U.S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska.
(d) Field investigations; applied research and design.
(e) Hydraulic prototype measurements of power plant transients at Oahe and Garrison Dam have been made to evaluate results of a comprehensive digital computer study made by the sponsoring offices, and to determine extent to which operation corresponds to design in order to develop a solution of the entire problem of power plant transients, with primary emphasis on governing stability. For different plant loadings, instantaneous pressure values at a number of locations in the power tunnel, the surge tank system, turbine scroll case, and draft tube were obtained simultaneously with instantaneous values of tunnel velocity, reservoir and tailwater elevations, turbine speed and gate opening, power output, and other elements (including governor system). Pressure and water level were measured with electrical pressure transducers, velocities were measured with pressure transducers mounted in probes projecting into the flow and connected to pitot-static tubes on cross struts in the penstock, and mechanical and electrical values were obtained with appropriate transducers. Measurements were recorded on about 90 channels of oscillograph and magnetic tape recorders. Data are being digitized by the Omaha District for computer analyses.

(3907) SHOALING PROCESSES.

- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
(d) Experimental; for design.
(e) The annual cost to the Federal Government of maintaining navigable channels in tidal waterways is estimated to be of the order of \$60,000,000. The Corps of Engineers Committee on Tidal Hydraulics has concluded that a thorough study of shoaling processes in tidal waterways would lead to improvements in channel design, dredging, and spoiling practices, and other maintenance techniques which would reduce this large expenditure. The Committee concludes that the following program of research is essential in arriving at the objective of reducing maintenance

cost: (1) Flume studies to determine the basic laws involved in the movement and deposition of muddy sediments; (2) flume studies to determine effects of repetitive scour and deposition on sedimentation; (3) the development of techniques for using radioactive tracers for observing the movement and deposition of sediments in nature; (4) the development of a simple and accurate instrument for in-place measurement of turbidity; (5) a study of the physical, chemical, and hydraulic factors involved in the stabilization of deposits in navigable channels; (6) determination of the effects of flocculation on shoaling; (7) prototype studies aimed at correlation of sedimentation phenomena in tidal waterways with physical, chemical, hydraulic, salinity, and other significant factors; and (8) classification of the sediments which constitute all major repetitive shoals in tidal waterways. Item (1) has been completed, and all pertinent reports have been published; item (2) is presently inactive; item (3) is in active status by the U. S. Army Engineer Waterways Experiment Station and U. S. Army Engineer Districts, Galveston and Wilmington; item (4) is presently inactive; item (5) was completed by the University of California, under terms of a contract with U. S. Army Engineer Waterways Experiment Station, and a preliminary report on the results of this study was prepared and submitted to the Committee on Tidal Hydraulics; item (6) is under study by the Committee on Tidal Hydraulics and Waterways Experiment Station, and a program of field research on this item has been formulated; and items (7) and (8) are in progress by the Waterways Experiment Station. No definite conclusions have yet been reached as a result of these studies.

(3908) MODEL STUDY OF NAVIGATION ENTRANCE TO ARKANSAS RIVER.

- (b) District Engineer, U.S. Army Engineer District, Vicksburg, Corps of Engineers, Vicksburg, Mississippi.
(d) Experimental; for design.
(e) A fixed-bed model reproducing to scales of 1:600 horizontally and 1:100 vertically about 33 miles of the Mississippi River near the mouths of the White and Arkansas Rivers, 57 miles of the lower Arkansas River, 12 miles of the lower White River, and the major portion of the White-Arkansas River backwater area was used for the investigation. The model was used to demonstrate alternate routes for the entrance to the Arkansas River navigation project, flow patterns, nature of overbank flow, effect of Arkansas-White Cutoff, and problems related to the location and alignment of the navigation entrance to the Arkansas River from the Mississippi River.
(h) Final report in preparation.

(3909) MODEL STUDY OF HANNIBAL LOCKS AND DAM, OHIO RIVER.

- (b) District Engineer, U. S. Army Engineer District, Pittsburgh, Corps of Engineers, Pittsburgh, Penna.
(d) Experimental; for design.
(e) A 1:120, fixed-bed, comprehensive model reproducing about 4 miles of the Ohio River and the lock and dam structures is being used to study navigation conditions in the approaches to the locks, determine suitability of the selected site, and develop modifications required to overcome any undesirable conditions found.
(f) Suspended.

(3911) MODEL STUDY OF MATAGORDA SHIP CHANNEL, TEXAS.

- (b) District Engineer, U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.
(d) Experimental; for design.

- (e) The fixed-bed model, constructed to scale ratios of 1:1,000 horizontally and 1:100 vertically, reproduced about 800 square miles of prototype area, including all of Matagorda Bay, part of the connecting bay system, and a portion of the Gulf of Mexico adjacent to Pass Cavallo. Tides and tidal currents were reproduced by one primary and one secondary tide generator, and fresh-water discharges of tributaries, together with the rainfall over the area, are introduced by means of weirs and flowmeters. Salt water was used in the model gulf to reproduce the prototype salinity regimen, and provisions were made for the injection of silt in the model for measurements of deposits on the bed of the model. Studies were made to determine: (1) The best location for the entrance channel; (2) the best route for the channel from the entrance to Point Comfort; (3) such protective works as may be required in the interests of navigation and maintenance of the channel; and (4) the effects of the deep-draft navigation channel on the salinity regimen of the bay system.
- (h) Final report in preparation.
- (3912) MODEL STUDY OF GALVESTON BAY (HARBOR), TEXAS.
- (b) District Engineer, U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.
- (d) Experimental; for design.
- (e) A movable-bed model, with scale ratios of 1:500 horizontally and 1:100 vertically, reproduces about 174.5 square miles of prototype area, including a small portion of Galveston Bay and a portion of the Gulf of Mexico extending 8 miles north of the north jetty, 6-1/2 miles south of the south jetty, and offshore to about the 50-foot contour of depth. Tides, tidal currents, littoral currents, and wave action in the Gulf of Mexico are reproduced. Studies have been made to determine: (1) Plans for relocation and stabilization of the jetty channel on an alignment and depth suitable for navigation of supertankers; (2) means of protecting the north jetty from undermining action of tidal currents; (3) shoaling characteristics of the relocated and deepened jetty (inner bar) channel and plans for minimizing shoaling; and (4) shoaling characteristics of the deepened outer bar channel; (5) construction procedures to be used in the prototype while constructing plan 2 channel realignment; and (6) shoaling characteristics of three proposed jetty modifications in conjunction with the plan 2 channel realignment. Tracer tests to investigate possible return of dredge spoil from the sea disposal area were also conducted.
- (g) (1) The jetty modification tests indicated that the outer 3,000 feet of the north jetty can be allowed to deteriorate to about elevation -12 feet MLT without detrimental effects on the shoaling characteristics of the entrance. (2) The tracer tests of possible return of dredge spoil from the sea disposal area indicated that wave directions south of about S45°E cause movement of bottom sediments toward and into the outer shoal area, while wave directions east of about S45°E do not move bottom sediment into the channel. These tests also indicated that most of the material which moves toward or into the channel originates in the northeasterly one-third of the disposal area, while material movement from the remaining two-thirds is generally to the east beach area south of the south jetty.
- (3914) MODEL STUDY FOR MODERNIZATION OF EXISTING LOCK, McALPINE LOCKS, OHIO RIVER.
- (b) District Engineer, U.S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.
- (d) Experimental; for design.
- (e) A 1:25 model which reproduced the filling and emptying system was used to develop feasible modifications which will improve prototype performance.
- (h) Final report in preparation.
- (3915) MODEL STUDY OF DROP STRUCTURE, GERING VALLEY PROJECT, GERING VALLEY, NEBRASKA.
- (b) District Engineer, U.S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska.
- (d) Experimental; for design.
- (e) The Gering Valley project in western Nebraska will consist of low rectangular drop structures designed for alluvial channels, a series of which will be located in the main Gering drain as well as in the tributaries. Structure widths will vary from 6 to 33 feet and lengths from 16 to 47 feet, with drop heights of 5 and 10 feet. A 1:12-scale model and a 1:33-scale model were used to examine the hydraulic performance of the drop structures with particular interest in basin performance, discharge capacity, and the extent and size of riprap required upstream and downstream of structure. Each model reproduced a typical drop structure, adjacent overbank areas, and about 300 feet of the approach and exit areas. The smaller scale model permitted more rapid modifications of the structure. Tests were conducted of 15 drop structure designs. These tests involved: (1) observation of flow conditions and investigation of scour tendencies above and below the structures; (2) effect of such factors as basin length, basin elements, and sill height and basin wall position; and (3) determination of riprap size and placement.
- (h) Final report in preparation.
- (3916) MODEL STUDY OF SPILLWAY, OAHAM DAM, MISSOURI RIVER, SOUTH DAKOTA.
- (b) District Engineer, U.S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska.
- (d) Experimental; for design.
- (e) A 1:50 model reproduced the remote, gated control structure which will serve as the spillway, the stilling basin, and approximately 1,700 feet of approach and 1,200 feet of exit channel. The model study was concerned with: (1) flow characteristics in the approach and exit channels; (2) discharge data for the spillway gates without downstream submergence; (3) the shape, arrangement, and locations of baffles for dispersal of energy downstream from the gate structure; (4) feasibility of a simple type of transition between the structure and the discharge channel; and (5) velocities on the apron below the structure and in a portion of the unlined exit channel.
- (g) Test results indicated that, while the spillway as originally designed functioned satisfactorily, a conventional-type stilling basin was not appropriate because of the lack of residual tail-water to force a hydraulic jump. A shallow, rectangular basin was developed which dispersed the smaller flows and eliminated surface waves noted at the larger flows with the original design basin. A schedule for use in operation of the spillway gates was developed. This schedule when used in conjunction with the shallow basin was the optimum method of dissipating flows on the apron until downstream submergence occurred. Tests of the exit channel indicated that sector walls could replace the concrete transitions below the rectangular section of the basin. The paved apron could be reduced in length some 45 feet, and the riprap section could also be reduced in length.
- (h) "Spillway for Oahe Dam, Missouri River, South Dakota; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-657, Sept. 1964. (Available on loan.)

- (3917) GENERAL SPILLWAY MODEL TESTS.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
 - (d) Experimental; for design.
 - (e) Tests are made on various elements of spillways to develop improved designs and to better define values of coefficients used in design formulas. A flume 70 feet long by 6 feet wide and 6 feet high comprises the test facility. Section models designed for study of particular elements of spillways are installed in the test flume. A series of tests was conducted on weirs of various heights to determine optimum shape from a consideration of discharge coefficients and pressures.
- (4382) HYDRAULIC PROTOTYPE TESTS.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D. C.
 - (d) Field investigations for applied research and design.
 - (e) The hydraulic prototype testing program of the Corps of Engineers is coordinated for complete coverage of needed testing, prevention of unnecessary duplication of testing facilities and tests, recommendations of instrument installations at projects where physical and hydraulic conditions will be suitable for obtaining data, and investigation of prototype hydraulic performance. Personnel and equipment are made available to Corps of Engineers Districts conducting hydraulic field tests. Assistance also is given in planning test facilities, analyzing data, and preparing reports. Hydraulic prototype tests related to and conducted partly under this study are described in item 4397 on McAlpine Lock emergency gate tests; item 3906 on power plant transients tests; item 5249 on prototype hawser-stress measurements, Jackson Lock, Tombigbee River, Ala.; item 5242 on culvert pressure tests, Greenup Locks and Dam, Ohio River, Ky. and Ohio; item 5243 on prototype pressure tests, Nolin Dam, Nolin River, Ky.; and Acoustic Flowmeter Installation and Prototype Tests of Outlet Works, Summersville Dam, Gauley River, West Virginia.
 - (g) Tests of the emergency gate performance of McAlpine Lock indicated stable gate operation under relatively severe flow conditions. Gate vibration was very low with no tendency to increase, indicating no elastic resonance with any fluctuating hydraulic load. Good agreement was found between prototype observations and results of a model study of the gate. Gate hoist loads were somewhat higher in the prototype than in the model, the variation being attributed to differences in gate construction or higher seal and reaction-roller friction in the prototype.
 - (h) "Emergency Gate Performance, McAlpine Lock, Ohio River, Kentucky; Hydraulic Prototype Tests." U. S. Army Engineer Waterways Experiment Station Miscellaneous Paper No. 2-622, February 1964. (Available on loan.)
- (4383) MODEL STUDY OF TURTLE CREEK CHANNEL IMPROVEMENT, PENNSYLVANIA.
- (b) District Engineer, U.S. Army Engineer District, Pittsburgh, Corps of Engineers, Pittsburgh, Pennsylvania.
 - (d) Experimental; for design.
 - (e) To evaluate proposed channel improvements and determine the necessity for raising bridges and modifying piers and abutments, a 1:50 model reproducing the lower 7,700 feet of Turtle Creek channel was used. The model included provisions for testing plans with the existing and improved channels in the lower, 1,500-foot reach of the channel.
 - (h) Final report in preparation.
- (4384) MODEL STUDY OF SPILLWAY, PROCTOR RESERVOIR, LEON RIVER, TEXAS.
- (b) District Engineer, U.S. Army Engineer District, Fort Worth, Corps of Engineers, Fort Worth, Texas.
 - (d) Experimental; for design.
 - (e) A 1:40 model reproducing a center bay and adjacent half bays of the spillway and stilling basin, and 300 feet of approach and exit areas, was used to verify the adequacy of the proposed shape for under-designed crests of low weirs with upstream faces sloping 3 on 2 and 3 on 3; to verify the accuracy of assumed discharge coefficients; and to determine the magnitude of pressures on the weir. Results will be used for this and other projects in the Fort Worth District.
 - (f) Completed.
 - (g) Decreasing depth of approach increased weir coefficients slightly; however, pier contraction coefficients were also increased. A crest shape tangent to upstream face of weir provided optimum pressure conditions and discharge coefficients. Cover plates were used over the bulkhead slots to reduce negative pressures in this area.
 - (h) "Spillway for Proctor Dam, Leon River, Texas; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-645, March 1964. (Available on loan.)
- (4385) MODEL STUDY OF BELLEVILLE LOCKS AND DAM, OHIO RIVER, OHIO AND WEST VIRGINIA.
- (b) District Engineer, U.S. Army Engineer District, Huntington, Corps of Engineers, Huntington, West Virginia.
 - (d) Experimental; for design.
 - (e) The project involves construction of a nonnavigable-type dam with parallel locks; the main lock will be 1,200 feet by 110 feet and the auxiliary lock 600 feet by 110 feet. A 1:120 fixed-bed model reproducing about 3 miles of the river was used to study navigation conditions in the lock approaches and the effects of the structures on flood stages.
 - (f) Suspended.
- (4386) MODEL STUDY OF HOLT LOCK AND DAM, WARRIOR RIVER, ALABAMA.
- (b) District Engineer, U.S. Army Engineer District, Mobile, Corps of Engineers, Mobile, Alabama.
 - (d) Experimental; for design.
 - (e) A 1:80 model, reproducing the structures, 4,800 feet of the approach channel and 4,800 feet of the exit channel, was used to study flow conditions in the lock approaches and in the approach and exit channels for all arrangements of the structures. A 1:36 section model reproducing one full bay and two adjacent half bays of the spillway and stilling basin was utilized for studies of the adequacy of the weir and stilling basin design. A 1:25 model reproducing 800 feet of the lock approach channel, intake manifolds, the 670-foot lock chamber, culverts, bottom laterals, outlet stilling basin, and 730 feet of the downstream exit channel was used to study various types of filling and emptying systems to determine the most advantageous system from the standpoints of rate of operations, degree of turbulence, and economy. A 1:15 model of a culvert valve was used to study proposed valve designs.
 - (h) Final report in preparation.
- (4387) MODEL STUDY OF WILLOW SPRINGS AND SAG JUNCTION DIVERSIONS, CHICAGO SANITARY AND SHIP CANAL, ILLINOIS.
- (b) Metropolitan Sanitary District of Greater Chicago, Chicago, Illinois.
 - (d) Experimental; for design.
 - (e) Tests were conducted on two 1:60 models, reproducing the diversion channels and a

- portion of the Sanitary and Ship Canal at each location, to determine the effect of crosscurrents on navigation and to verify or further develop the hydraulic design of the diversion channels and appurtenant hydraulic structures. A 1:16 section model was used for study of control structures.
- (h) Final report in preparation.
- (4388) SECTION MODEL STUDY OF SPILLWAY, TYPICAL LOW HEAD NAVIGATION DAM, ARKANSAS RIVER, ARKANSAS.
- (b) District Engineer, U.S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
- (d) Experimental; for design.
- (e) A 1:25 section model, reproducing a 5-foot depth of approach channel, one 60-foot gate bay and two adjacent half bays, the spillway, stilling basin, and outlet channel, was used to determine optimum gate sill and pier nose shapes, spillway capacity with full and partial gate openings for both free and submerged flows, stilling basin performance, and riprap requirements for a typical low-head navigation dam. Additional tests (which will be reported in an appendix to the final report) were initiated to (a) investigate the possibility of eliminating stilling basins at certain structures founded on rock and with considerable tailwater cushion, (b) determine flow conditions and velocities downstream of a trapezoidal gate sill, and (c) determine stilling basin performance and riprap requirements for the conditions of locks and dams 5 and 7.
- (f) Completed.
- (g) Test results of the main study indicated that: (a) The parabola, $X^2 = 40Y$, is the optimum gate sill shape; (b) an ogival pier nose is slightly more efficient than a semi-circular nose; (c) apron elevations in the range of elevations tested do not affect discharge characteristics; (d) one row of 4-foot-high baffle piers and a 3-on-4 sloping, 4-foot-high end sill comprise the optimum stilling basin; (e) riprap downstream of the stilling basin is most stable when placed on a 1-on-6 slope; and (f) extension of the gate piers from the toe of the gate sill to the end of the stilling basin produces a more uniform scour pattern in the exit channel. The additional tests (described in (e)) indicated that the elimination of stilling basins was not practical for the conditions investigated. However, a 40-foot-long, horizontal apron terminated by a 4-foot-high sloping end sill provided satisfactory performance and was found to be more effective in dissipating energy than were various roller buckets.
- (h) "Spillway for Typical Low-Head Navigation Dam, Arkansas River, Arkansas; Hydraulic Model Investigation". U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-655, September 1964.
- (4390) MODEL STUDY OF CANNELTON LOCKS AND DAM, OHIO RIVER, INDIANA AND KENTUCKY.
- (b) District Engineer, U.S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.
- (d) Experimental; for design.
- (e) The project involves the construction of a nonnavigable dam with parallel locks, the main lock to have clear dimensions of 1200 by 110 feet and an auxiliary lock, 600 by 110 feet. A 1:120 model reproducing about 9 miles of the river is used for investigation of navigation conditions in the lock approaches, effects of the structures on flood stages, to obtain data for development of rating curves, and to determine the effect of powerhouse installation on flow and navigation conditions. A 1:25 model, reproducing 500 feet of the lock approach channel, intake manifolds, the 1270-foot lock chamber, culvert, sidewall port manifolds, outlets, and 200 feet of the downstream exit channel is being used to determine the suitability of a sidewall port filling system under heads and submergences which will obtain at other locks on the Ohio River.
- (g) Tests on the 1:120 model indicated that the powerhouse should be placed on an angle of 7 degrees 45 minutes with the axis of the dam, and that satisfactory navigation conditions could be obtained during floods by degrading a portion of the left overbank upstream of the powerhouse entrance channel. Lock model tests indicated that satisfactory performance should be obtained with a sidewall port arrangement for a 110- by 1200-foot lock based on the following recommendations: (1) Port-area to culvert-area ratios should be about 0.95. (2) Ports should be spaced 28 feet on centers. (3) The port group should extend over about 50 percent of the lock chamber, and be centered in the chamber. (4) Triangular deflectors or recesses are desirable at the upstream one-third of the ports.
- (4391) MODEL STUDY OF LOCK AND DAM NO. 3, ARKANSAS RIVER, ARKANSAS.
- (b) District Engineer, U.S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
- (d) Experimental; for design.
- (e) A movable-bed model reproducing about 13 miles of the Arkansas River and adjacent overbank area, constructed to a scale of 1 to 120 horizontally and 1 to 80 vertically, is being used to determine the suitability of the proposed site for the lock and dam structure, the effects of proposed regulating works in the vicinity including a cutoff, and modifications which might be required to provide adequate channel depths in the lock approaches and safe navigation conditions with minimum maintenance.
- (g) Indications of the relative scour and scour patterns which could be expected with different cofferdam plans and degree of protection required were determined. A dike will be required along the left bank extending upstream above the upper guard wall to eliminate navigation difficulties with overbank flow.
- (4392) EXTENSION OF LA GUARDIA FIELD RUNWAY, NEW YORK.
- (b) Port of New York Authority.
- (d) Experimental; for design.
- (e) The existing New York Harbor model was used for tests to determine the effects of certain proposed fills or pile-supported structures in East River, for the purpose of extending the North-South and East-West runways at La Guardia Airport, on the hydraulic and flushing characteristics of the surrounding areas. The fills or the pile-supported structures would close Rikers Island Channel to navigation; therefore, the plan tested included an alternate route for deep-draft vessels now using the channel.
- (f) Completed.
- (g) Tests of solid fills showed that such plans would have detrimental effects on the flushing of pollutants discharged in the vicinity. Tests of the pile-supported structures showed that these plans would have no major effects on the hydraulic regimens of the problem area. Current strengths in adjacent reaches of East River would be increased slightly, but would still be well below existing maximum currents in other areas. Crosscurrents at the entrance to the alternate ship channel might create navigation problems for ships entering or leaving this channel during strengths of flood or ebb, but no problem should exist at or near times of current slack.
- (h) "Effects of Proposed Runway Extensions at LaGuardia Airport on Tides, Currents,

Shoaling, and Dye Dispersion; Hydraulic Model Investigation". U. S. Army Engineer Waterways Experiment Station Miscellaneous Paper No. 2-641, April 1964. (Available on loan.)

(4395) DISPERSION STUDIES IN NEW YORK HARBOR MODEL.

- (b) Interstate Sanitation Committee.
- (d) Experimental; for design.
- (e) The existing New York Harbor model was used for a comprehensive study of the diffusion patterns from most of the major sewer outfalls in New York Harbor. Model tests were conducted using conservative fluorescent dyes as tracers, and the results will be used for planning the construction of additional sewage treatment facilities. Results were furnished by the Interstate Sanitation Commission for analysis.
- (f) Completed.

(4396) MODEL STUDY OF COLUMBIA RIVER ESTUARY, ENTRANCE TO OAK POINT, OREGON AND WASHINGTON.

- (b) District Engineer, U.S. Army Engineer District, Portland, Corps of Engineers, Portland, Oregon.
- (d) Experimental; for design.
- (e) The model reproduces the lower 52 miles of the Columbia River and pertinent offshore areas to linear scales of 1:500 horizontally and 1:100 vertically. Tides and tidal currents, density currents, waves, and other phenomena significant to the movement and deposition of sediments are reproduced and studied. All portions of the model are presently of the fixed-bed type, while some portions are to be converted to the movable-bed type at a later date. The purposes of the study are to determine the need for and to develop optimum plans for rehabilitation of existing jetties and proposed additional improvements; to investigate future shoaling developments in the entrance channel and in the reach between the entrance and Oak Point, and means of alleviating such shoaling; and to investigate existing and proposed spoil-disposal areas to establish locations that will not permit movement of material back to the channel.
- (g) Fixed-bed shoaling tests indicated that a substantial reduction in entrance channel shoaling (perhaps as great as 20 percent) might be realized by allowing the outer 2,000 feet of the south jetty, which is immediately shoreward of the existing terminal block, to be degraded to elevation -15 mean lower low water. Similar tests on the north jetty indicated a slight reduction of entrance channel shoaling if that jetty is restored to original conditions. Movable-bed studies are scheduled for both the north and south jetties to determine their optimum lengths. Velocity measurements indicated that if the Sand Island dikes are allowed to deteriorate, the shores of the islands will erode rather rapidly. Fixed-bed shoaling tests indicated that material placed in Disposal Areas C and D will not migrate into the navigation channel.

(4397) PROTOTYPE TESTS OF EMERGENCY GATE, McALPINE LOCKS, OHIO RIVER, KENTUCKY.

- (b) District Engineer, U.S. Army Engineer Dist., Louisville, Corps of Engrs., Louisville, Ky.
- (d) Experimental; for design.
- (e) Prototype measurements of the forces acting on the downstream leaf of a two-leaf, vertical-lift emergency gate (531 kips dry weight) were made to determine acceptability of the gate under flowing water conditions. Measurements included tension in the dead end of the hoist fall lines, gate-end elevations, and gate vibration. The prototype downpull and gate vibration were compared with the results of a model study.

- (f) Completed.
- (g) Results of the tests indicated stable gate operation under relatively severe flow conditions. Gate vibration was very low with no tendency to increase, indicating no elastic resonance with any fluctuating hydraulic load. Good agreement was found between prototype observations and results of a model study of the gate. Gate hoist loads were somewhat higher in the prototype than in the model, the variation being attributed to differences in gate construction or higher seal and reaction-roller friction in the prototype.
- (h) "Emergency Gate Performance, McAlpine Lock, Ohio River, Kentucky; Hydraulic Prototype Tests". U. S. Army Engineer Waterways Experiment Station Miscellaneous Paper No. 2-622, February 1964.

(4398) MODEL STUDY OF SPILLWAY, AMISTAD DAM, RIO GRANDE.

- (b) District Engineer, U.S. Army Engineer District, Fort Worth, Corps of Engineers, Fort Worth, Texas.
- (d) Experimental; for design.
- (e) A 1:70 model reproducing one-half of the river for a distance of 1,500 feet upstream and 2,500 feet downstream, one powerhouse, and one-half of the 950-foot-wide, 16-bay structure including the spillway and stilling basin was used to verify the capacity of the ogee weir, and to determine (1) the hydrostatic pressures on the spillway crest and gate piers, (2) the performance of both a horizontal apron and a double-stage stilling basin, and (3) optimum length and height of spillway and stilling basin training walls.
- (f) Completed.
- (g) The theoretical spillway rating curve and the expected hydrostatic pressures on the weir crest were in close agreement with those determined with the model. Stilling basin performance of the original design was found to be unsatisfactory. However, satisfactory stilling basin designs were developed for three apron elevations. The height of the original spray wall was found to be inadequate due to the effect of the abutment on the water-surface profile. The original height and length of the stilling basin training walls were found to be the optimum.
- (h) "Spillway for Amistad Dam, Rio Grande, Mexico and United States; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-653, August 1964. (Available on loan.)

(4593) MODEL STUDIES OF MILLERS FERRY LOCK AND DAM, ALABAMA RIVER, ALABAMA.

- (b) District Engineer, U. S. Army Engineer Dist., Mobile, Corps of Engineers, Mobile, Ala.
- (d) Experimental; for design.
- (e) The project will include a nonnavigable dam with a gated and an overflow section, a lock on the left bank having clear dimensions of 600 by 84 feet, and a powerhouse. A 1:100 model, reproducing about 3.1 miles of river, will be used to investigate navigation conditions through an existing bridge and in the lock approaches, the effects of the structures on flood stages, and the effects of powerhouse operations on navigation conditions. A 1:50 model of a section of the gated portion of the dam, reproducing 600 feet of the approach channel, a 50-foot-wide gate bay with piers and 28.5 feet of each adjacent gate bay, a 125-foot-wide section of the stilling basin, and 700 feet of the exit area, was used to determine flow characteristics over the spillway and verify the adequacy of the stilling basin design. A 1:25 model reproducing 700 feet of the lock approach channel, the 600- by 84-foot lock chamber, the entire culvert system, and 800 feet of

the downstream exit channel is being used to study the suitability of the longitudinal floor culvert system for filling and emptying the lock under heads and submergences which will obtain at the site.

- (f) Tests completed; final reports on 1:100 and 1:25 models in preparation.
- (g) Results in the spillway section model indicated that flow separated from the downstream face of the original gate sill, and a parabolic shape was added to guide flow into the stilling basin. The spillway rating curves were determined with full and partial gate openings for both gate sill shapes. The stilling basin as originally designed functioned satisfactorily below the curved sill shape, but alterations were tested in an effort to reduce construction costs. Alterations consisted of (1) shortening the apron by 10 feet, and (2) sloping the apron down on a 1-on-20 slope from the toe of the gate sill to the end sill. The altered basins were not as efficient as the original design; therefore, the original design was recommended. Results in general model indicated the need for modification of the excavation along the left bank to facilitate the movement of downbound tows leaving the lock. In the lock studies, two satisfactory floor culvert arrangements were developed. One arrangement was adapted to the particular foundation conditions existing at the Millers Ferry Lock site which confined the culvert system to the middle third of the lock chamber. The second arrangement was developed for locations with less restrictive foundation conditions.
- (h) "Spillway, Millers Ferry Lock and Dam, Alabama River, Alabama; Hydraulic Model Investigation". U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-643, February 1964. (Available on loan.)
- (4594) MODEL STUDY OF SPILLWAY, SHELBYVILLE DAM, KASKASKIA RIVER, ILLINOIS.
 - (b) District Engineer, U. S. Army Engineer Dist., St. Louis, Corps of Engineers, St. Louis, Missouri.
 - (d) Experimental; for design.
 - (e) A 1:40 model reproducing 1,550 feet of the approach channel, the gated spillway with sloping chute leading to a conventional hydraulic-jump type stilling basin, a portion of the earth embankment on each side of the spillway, outlet works consisting of two sluices beneath the 9-foot-wide crest piers, and 1,150 feet of the exit channel was used to study the overall hydraulic performance of the spillway and outlets of the sluices, and to verify chute and stilling basin designs.
 - (f) Tests completed.
 - (g) Adequate spillway capacity and flow conditions at the abutments were obtained by placing rock dikes at the abutment to guide flow into the weir. The diversion blockout located in the center gate bay was found to be adequate and satisfactory for the release of the expected diversion flows.
 - (h) Final report in preparation.
- (4595) MODEL STUDY OF COLUMBIA LOCK AND DAM, OUCHITA RIVER, LOUISIANA.
 - (b) District Engineer, U. S. Army Engineer Dist., Vicksburg, Corps of Engineers, Vicksburg, Mississippi.
 - (d) Experimental; for design.
 - (e) The project involves construction of a cutoff channel about 5,600 feet long with a bottom width of 522 feet, a gated structure (consisting of four tainter gates each 50 feet wide and 26 feet high) located about midway of the cutoff, a 200-foot-wide navigable pass on the right of the dam, and a 600- by 84-foot lock on the left. A 1:100 model, reproducing about 2.6 miles of the river, was used to investigate navigation conditions in the approaches to the lock and navigable pass, and the effects of the structures on flood stages.
 - (f) Final report in preparation.
- (4596) MODEL STUDY OF OVERFLOW EMBANKMENTS FOR LOW HEAD DAM ON ARKANSAS RIVER, ARKANSAS.
 - (b) District Engineer, U. S. Army Engineer Dist., Little Rock, Corps of Engineers, Little Rock, Arkansas.
 - (d) Experimental; for design.
 - (e) A 1:4 model reproducing a 40-foot-wide section of overflow embankment including 90 feet of approach channel, the embankment with upstream and downstream slopes of 1 on 3 and 1 on 4, respectively, and crown widths of 20 and 35 feet, and 140 feet of exit channel was used to investigate the stability of various gradations of protective stones and types of embankments, and furnish data on which an economical and workable design of the overflow embankments can be based. The crown was tested with and without a paved roadway. In addition, a 1:12-scale section model was tested in a 1-foot-wide, glass-sided flume to determine pressures on the crest and downstream slope of the embankment.
 - (f) Completed.
 - (g) Test results indicated that the combined effect of embankment height and crown width on riprap stability is small, that embankments supporting roadways can be considered slightly more stable than those without roadways, that all stone failure occurred in the zone of free (rather than submerged) flow, and that the effective or critical size stone of a particular gradation is that which represents 60 to 65 percent by weight of the total. Variation in stone roughness had no discernible effect on the discharge characteristics of the overflow embankments within the range of heights (3 to 10 feet) and crown widths tested. Discharge coefficients applicable to the two types of embankments were determined for both free and submerged flows, and empirical equations were developed. Also, tests indicated that much smaller stone can be used on the lower, submerged portions of the downstream slope of the embankments if warranted economically.
 - (h) "Stability of Riprap and Discharge Characteristics, Overflow Embankments, Arkansas River, Arkansas; Hydraulic Model Investigation". U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-650, June 1964. (Available on loan.)
- (4598) MODEL STUDY OF DROP STRUCTURE, CAYUGA INLET, ITHACA, NEW YORK.
 - (b) District Engineer, U. S. Army Engineer Dist., Buffalo, Corps of Engineers, Buffalo, N. Y.
 - (d) Experimental; for design.
 - (e) A 1:20 model, reproducing 300 feet of the trapezoidal approach channel, the rectangular, 80-foot-wide drop structure, the 60-foot-long basin with baffle piers and end sill, and about 400 feet of trapezoidal exit channel, was used to confirm the suitability of the drop structure, and if indicated, to develop advantageous modifications thereto. Of particular concern was the magnitude of channel velocities below the structure.
 - (h) Final report in preparation.
- (4599) MODEL STUDY OF CONTROL STRUCTURES, LITTLE SIOUX RIVER, LITTLE SIOUX, IOWA.
 - (b) District Engineer, U. S. Army Engineer Dist., Omaha, Corps of Engineers, Omaha, Nebraska.
 - (d) Experimental; for design.
 - (e) The structure will consist of a low, 50-foot-wide, rectangular drop located in the control channel with rock protection downstream and on adjacent berms. A 1:30 model, reproducing

about 700 feet of the approach channel and berms upstream of the structure with portions of the adjacent levees, the drop structure, and about 1,300 feet of the channel and berms below the structure was used to study the placement of riprap materials in the vicinity of the structure, and the discharge capacity of the structure.

(h) Final report in preparation.

(4600) RADIOACTIVE TRACER TESTS OF SEDIMENT, CAPE FEAR RIVER, NORTH CAROLINA.

(b) District Engineer, U. S. Army Engineer Dist., Wilmington, Corps of Engineers, Wilmington, North Carolina.

(d) Experimental; field investigation.

(e) The movement of material from dredge spoil areas was investigated using labeled sediment to determine if spoil material moves into the wharf areas at Sunny Point Army Terminal. The sediment was labeled using auric chloride (Gold-198) solution adsorbed on existing sediment. Material was placed at four locations under two extreme tide conditions. Movement of sediments was observed for two weeks using instruments on a small boat.

(f) Completed.

(g) Test results showed that significant amounts of the spoil material are transported into the north and center wharf basins, regardless of whether the material is placed during rising or falling tide.

(h) "Radioactive Sediment Tracer Tests, Cape Fear River, North Carolina". U. S. Army Engineer Waterways Experiment Station Miscellaneous Paper No. 2-649, May 1964.

(4601) MODEL STUDY OF POLLUTION, CONEY ISLAND CREEK, NEW YORK.

(b) New York City Department of Health, New York, New York.

(d) Experimental; for design.

(e) An existing model of New York Harbor was used to investigate diffusion patterns from sewage treatment plant outfalls and combination sewer and storm outfalls with special attention to contamination of bathing beaches and other recreational facilities. Plans for diverting pollution away from certain critical areas were also investigated.

(f) Completed.

(4602) LOCK FILLING AND EMPTYING SYSTEM.

(b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.

(d) Experimental; applied research.

(e) A 1:15 valve model used to develop the vertically framed Holt Lock valve was utilized to compare the performance of this valve with that of the McNary type valve. The Holt valve was 12.5 by 12.5 feet and the McNary valve was 11 feet wide by 12 feet high. Therefore, for tests of the McNary valve the valve was expanded to 12.5 by 12.5 feet by additions of 1.5 feet in width and 0.5 foot in height to the center portions of the valve.

(h) Preparation of final report in progress.

(4603) MODEL STUDY OF FILLING AND EMPTYING SYSTEM FOR LOW-LIFT LOCKS, ARKANSAS RIVER, ARKANSAS.

(b) District Engineer, U. S. Army Engineer Dist., Little Rock, Corps of Engineers, Little Rock, Arkansas, and other interested Corps of Engineers offices.

(d) Experimental; for design.

(e) A 1:25 model, reproducing 700 feet of lock approach channel, intake manifolds, a 670-foot-long lock chamber, culvert, sidewall port manifolds, outlet manifold, and 700 feet of downstream channel is being used to determine an optimum port arrangement for the filling and emptying system for low-lift locks. An intake is to be developed for use in all tests. Then optimum shape, size,

number, spacing, and location of the ports in the lock chamber as related to culvert size will be determined for a full range of heads and submergences. The Little Rock District is sponsoring the first phase of the tests in which a 12- by 12-foot culvert will be used. Tests of other size culverts will be sponsored by interested Corps of Engineers offices for the purpose of standardizing lock design for 600- by 110-foot locks.

(f) Tests completed.

(g) Results of the generalized test indicated that a satisfactory sidewall port arrangement for a 110- by 600-foot lock should result from the following recommendations:

(1) Port-area to culvert-area ratio should be about 0.95. (2) Ports should be spaced 28 feet on centers. (3) The port group should extend over about 50-60 percent of the lock chamber and be centered about the midpoint of the lock chamber or a point slightly downstream. (4) Triangular deflectors or recesses are desirable at the upstream one-third of the ports. Filling and emptying characteristics were obtained for a range of lifts and submergences for the optimum arrangements of 14 type A ports (type 35) and 13 type D ports (type 56).

(h) Final report in preparation.

(4604) MODEL STUDY OF INTAKE AND FLOOD-CONTROL OUTLET, DEGRAY DAM, CADDO RIVER, ARKANSAS.

(b) District Engineer, U. S. Army Engineer Dist., Vicksburg, Corps of Engineers, Vicksburg, Mississippi.

(d) Experimental; for design.

(e) A 1:23 model reproducing the intake tower and a portion of the reservoir, the diversion tunnel, stilling basin, and 240 feet of the exit channel is being used to develop a conventional hydraulic jump-type stilling basin, and to study flow through the intake tower, elbow, tunnels, and at the flow-control device at the end of the flood-control tunnel.

(f) Tests completed.

(g) A cylinder-gate intake tower functioned with less head loss and less surging than did the slide-gate intake tower. Pressures in the tunnel and elbow were positive and no zones of separation were evident. Pressures in the flood-control transitions approximated the area curve. The stilling basin developed for the large diversion releases was found to be adequate for dissipation of the high-energy flood-control releases.

(h) Final report in preparation.

(4605) MODEL STUDY OF BREAKWATER, KAHULUI HARBOR, HAWAII.

(b) District Engineer, U. S. Army Engineer Dist., Honolulu, Corps of Engineers, Honolulu, Hawaii.

(d) Experimental; for design.

(e) Stability tests were conducted in a concrete wave flume 119 feet long, 12.5 feet wide, and 4 feet deep, on section models of both the east and west breakwater heads, and sections of the trunk of the east breakwater constructed to a linear scale of 1:68.5 to develop designs for repair of the damaged breakwater heads and trunks. Tests conducted were concerned with the stability of 35- and 50-ton tribars.

(f) Completed.

(g) Stability tests indicated that a repair section consisting of a cover layer of 30-ton tribars placed pell-mell over the existing slopes of the trunk of the east breakwater would be adequate to withstand the attack of waves 34 feet in height. It was found that a repair section consisting of a cover layer of 50-ton tribars from +20 feet mllw down to -20 feet mllw, and 35-ton tribars from -20 feet mllw down to the toe of the slope, would be adequate to withstand the attack of the 34-foot-high waves on the heads of both the east and west breakwaters.

- For these conditions the slope of the repaired head sections was about 1:3.
- (h) "Designs for Rubble-Mound Breakwater Repair, Kahului Harbor, Maui, Hawaii; Hydraulic Model Investigation". U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-644, February 1964. (Available on loan.)
- (5228) CRITERIA FOR THE DESIGN OF SMALL-BOAT HARBORS.
- (b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.
 - (d) Experimental; applied research.
 - (e) Theoretical and experimental studies are being conducted to develop equations and experimental coefficients for use in predicting the motion of small boats moored to floating docks under the action of progressive- and standing-wave systems; determine the optimum shape of harbor and types of perimeter with respect to the response characteristics of small-craft harbors and the surging of moored craft in the harbors; and provide design criteria for protective structures at the entrance to small-craft harbors.
- (5229) GENERAL COASTAL INLET STUDIES.
- (b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.
 - (d) Experimental; applied research.
 - (e) This is a general study to develop means for computing discharge and velocity distribution through tidal inlets, leading to determination of tidal prisms and water-surface elevations in inner bay systems; and to determine the factors involved in both inner and outer bar formation, the shoaling of inlet channels, and the stability of inlet shape and location. The project will consist of the following three phases: (1) Tests in four generalized test facilities, three of which will be located at the Waterways Experiment Station and the fourth at the Coastal Engineering Research Center; (2) analysis of results of these tests by the Waterways Experiment Station, the Coastal Engineering Research Center, and the Committee on Tidal Hydraulics; and (3) field observations under sponsorship of the Committee on Tidal Hydraulics to confirm the principles developed. Construction of Facility A at U. S. Army Engineer Waterways Experiment Station was completed except for the pumping plant and control system, which is being fabricated under contract. Design of Facilities B and C at U. S. Army Engineer Waterways Experiment Station was in progress.
- (5230) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 4, ARKANSAS RIVER.
- (b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
 - (d) Experimental; for design.
 - (e) A 1:120 fixed-bed model, reproducing about 5 miles of the Arkansas River and adjacent overbank areas, the lock and dam structures, and all bridges and other structures that might affect flow conditions, is being used to determine the suitability of the proposed site for the lock and dam structure, the effects of regulating works in the lower approach, and to develop modification which might be required to overcome any undesirable navigation conditions.
 - (g) A site suitable for a mooring area was selected. The change in the design of the guard wall had little effect on navigation. Removal of the point along the right bank at the Rob Roy Bridge reduced velocities at the bridge with little change in navigation conditions in the upper lock approach.
- (5231) MODEL STUDY OF NAVIGATION CONDITIONS, OZARK LOCK AND DAM, ARKANSAS RIVER.
- (b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers,
- Little Rock, Arkansas.
- (d) Experimental; for design.
 - (e) A 1:120, fixed-bed model, reproducing about 3 miles of the Arkansas River, adjacent overbank areas, the lock and dam structures, and all bridges and other structures that might affect flow conditions, is being used to determine the suitability of the proposed site for the lock and dam structures, and to develop modifications which might be required to overcome any undesirable navigation conditions.
 - (g) Profiles showing effect of structures on water-surface elevations, and velocities along overflow embankments were obtained.
- (5232) MODEL STUDY OF STILLING BASIN, HUNTINGTON RESERVOIR, WABASH RIVER.
- (b) District Engineer, U. S. Army Engineer District, Louisville, Kentucky.
 - (d) Experimental; for design.
 - (e) A gated spillway with six conduits through the spillway section is proposed for Huntington Dam. A 1:60 model of a 60-foot-wide section of the spillway and stilling basin and 500 feet of the exit channel was used in the study. The spillway gate piers and conduits through the spillway were not reproduced; however, the model was adjusted to simulate the increased head that would have obtained with crest piers and abutments present. The purposes of the study were: (1) To insure good energy dissipation in the stilling basin at low and intermediate flows, and safe conditions at high flows; (2) to study the effect of the flatter than usual downstream spillway slope (10 horizontal to 12 vertical) on basin action; and (3) if the originally proposed basin design was found to be unsatisfactory, to make revisions necessary to secure the desired results.
 - (h) Final report in preparation.
- (5233) MODEL STUDY OF SUBMERGED SILLS, ST. CLAIR RIVER.
- (b) District Engineer, U. S. Army Engineer District, Detroit, Corps of Engineers, Detroit, Michigan.
 - (d) Experimental; for design.
 - (e) Construction of submerged sills at the head of the St. Clair River is proposed as a means of raising the level of Lake Huron. A 1:60, fixed-bed model reproduces 3 miles of the river from Lake Huron downstream, and has provisions for simulating sediment movement and shoaling. This model is being used to study effects of one or more submerged sills at different locations on backwater effect, to study sedimentation characteristics, and to study velocities and current directions. A 1:20-scale section model installed in an existing, 2.5-ft-wide flume is being used to investigate the stability of the submerged sills and the ability of 15-ton precast units and various sizes of stone to withstand propeller wash with an initial velocity of 25 feet per second.
 - (g) Tests in the comprehensive model indicated that with various combinations of sills, the level of the lake could be raised from 0.25 to 0.75 foot.
- (5234) MODEL STUDY OF SEAWALL, TEXAS CITY, TEXAS.
- (b) District Engineer, U. S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.
 - (d) Experimental; for design.
 - (e) A levee and seawall system has been proposed to protect Texas City and adjacent areas of the shore of Galveston Bay from flooding caused by hurricanes. To develop designs for (1) vertical-faced seawalls, (2) rubble-mound structures to protect the natural ground at the base of a vertical wall on its bayside, and (3) rubble-mound armor layers to protect

the bayside slope and crown of an earth levee, 1:35 section models of the structures are being tested in a concrete flume 119 feet long, 5 feet wide, and 4 feet deep. Model waves are generated by a plunger-type wave machine, and measured and recorded electrically.

- (f) Tests completed.
 - (g) To stabilize the type 1 design, when attacked by 6-second, 15-foot waves, 6-ton stones instead of 3.3-ton stones were required at the bayside toe. The landside slope was made stable by using 3.3-ton stones instead of riprap. The type 2 and type 3 designs were made stable under the attack of 6-second, 15-foot waves by using a mound of 1- to 1-1/2-ton stones to scotch the toe of the 6-ton cover layers. Pressure distribution tests on the composite seawall design and on the simple vertical-faced seawall showed that the forces acting on the vertical wall section were greater than those obtained from Sainflou's theory for nonbreaking waves, and less than those obtained from Minikin's formula for breaking waves.
 - (h) Final report in preparation.
- (5235) MODEL STUDY OF BESSIE CUTOFF, MISSISSIPPI RIVER.
- (b) District Engineer, U. S. Army Engineer District, Memphis, Corps of Engineers, Memphis, Tennessee.
 - (d) Experimental; for design.
 - (e) The proposed Bessie Cutoff would eliminate the river bend at New Madrid, Mo., and shorten the river about 20 miles. A model, reproducing 85 miles of the river to a horizontal scale of 1:500 and a vertical scale of 1:100, is being used to obtain indications of the probable effects of various degrees of cutoff development on velocities, current directions, water-surface profiles, navigation depths, channel meandering tendencies, and general navigability of the affected reach. The model is of the fixed-bed type with provision for converting to a movable bed the reaches expected to be affected appreciably by the cutoff.
 - (f) Tests completed; final report in preparation.
 - (g) Tests to determine effects of cutoff at intermediate and final development stages and to determine sediment movement as affected by the cutoff were accomplished.
 - (h) "Preliminary Report of Model Study of Bessie Cutoff, Mississippi River; Hydraulic Model Investigation". U. S. Army Engineer Waterways Experiment Station Miscellaneous Paper No. 2-680, October 1964. (Available on loan.)
- (5237) MODEL STUDY OF WAVE ACTION, HALF MOON BAY HARBOR, CALIFORNIA.
- (b) Dist. Engr., U. S. Army Engr. Dist., San Francisco, Corps of Engrs., San Francisco, Calif.
 - (d) Experimental; for design.
 - (e) Half Moon Bay Harbor is partially protected from severe storms by a 2,620-foot-long west breakwater and a 4,420-foot-long east breakwater which enclose a 245-acre area with 6-foot or greater water depths, and form a 600-foot-wide entrance channel 24 feet deep. During storms, a severe concentration of wave energy at the entrance travels into the inner harbor, creating intolerable anchorage conditions. A model study is being conducted to determine: (1) The relative influence of the waves that approach the harbor from the several storm directions; (2) the effects of wave action inside the harbor believed to result from wave energy passing through the voids in the breakwaters in addition to that through the entrance; and (3) the most feasible of several plans proposed for reducing the effects of wave and surge action now prevailing. The 1:100 model, which covered an area of about 13,000 square feet, reproduced all the inner harbor, breakwater

system, and sufficient bay area to permit simulation of waves from all critical storm directions. Waves were generated by a 60-foot-long, plunger wave machine, and measured and recorded electrically.

- (f) Completed.
 - (g) Test results indicated that during storms from the southwesterly to south directions, severe wave action obtains inside the harbor at the docks and piers as alleged. The shoals southerly of the harbor entrance cause a concentration of wave energy at and in the present harbor entrance. Several breakwater plans studied adequately reduced the wave energy entering the harbor during severe storms. It was concluded that an added section of rubble-mound breakwater about 1,050 feet long, which would extend the existing west breakwater in a southeasterly direction from the present entrance and provide a revised navigation entrance about 350 feet wide, would ensure the desired protection.
 - (h) "Wave Action and Breakwater Location, Half Moon Bay Harbor, Half Moon Bay, California; Hydraulic Model Investigation". U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-668, in publication. (Available on loan.)
- (5238) MODEL STUDY OF SPILLWAY, STOCKTON DAM, SAC RIVER, MISSOURI.
- (b) District Engineer, U. S. Army Engineer District, Kansas City, Corps of Engineers, Kansas City, Kansas.
 - (d) Experimental; for design.
 - (e) A 4-gated, ogee spillway and one 45,000-kilowatt powerhouse unit located in a concrete nonoverflow section adjacent to the spillway are proposed for Stockton Dam. A 1:60 model reproducing 1,700 feet of the approach area, the entire spillway and powerhouse, the stilling basin, and 1,100 feet of the exit channel was used to investigate the hydraulic adequacy of the spillway, stilling basin, and appurtenances, and determine any desirable modifications for various operating conditions.
 - (f) Tests completed.
 - (g) The capacity of the spillway as determined in the model was about 6 percent greater than the computed capacity. Efforts to reduce the length of the spillway to take advantage of this increased efficiency were abandoned when rerouting the spillway design flood gave a reduction in surcharge of only 0.3 foot (maximum pool elevation of 905.9 in lieu of elevation 906.2). While the stilling basin of original design performed adequately it was found that economies could be effected by reducing the excavation in the basin (raising basin from elevation 733 to 738) and decreasing the size of the stilling basin elements. The adopted design stilling basin (type 3) provided a depth of about 0.85 D_2 and a length of about 3.0 D_2 at the spillway design flood. (D_2 , the theoretical depth for formation of a hydraulic jump at the design discharge, is 74.2 feet, neglecting losses.)
 - (h) Final report in preparation.
- (5239) MODEL STUDY OF WAVE ACTION, MARINA DEL REY, VENICE, CALIFORNIA.
- (b) District Engineer, U. S. Army Engineer District, Los Angeles, Corps of Engineers, Los Angeles, California.
 - (d) Experimental; for design.
 - (e) Marina Del Rey is a small-craft harbor consisting of eight lateral basins off a main channel which opens into Santa Monica Bay. A 1:175 model of the entire harbor area was used to study wave action within the project area and to investigate and develop remedial plans for alleviating adverse wave and surge action presently restricting full usage of the harbor. Waves were generated

- with a 40-foot-long, vertical-plunger wave machine, and were measured and recorded electrically.
- (f) Completed.
- (g) Final analysis of model test data resulted in recommendation of a wing-type offshore breakwater, 2,325 feet in length, to be constructed 640 feet seaward of the ends of the channel jetties. This construction would reduce wave action within the harbor to an acceptable level.
- (h) "Selection of Optimum Plan for Reduction of Wave Action in Marina Del Rey, Venice, California; Hydraulic Model Investigation". U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-671, in publication. (Available on loan.)
- (5240) MODEL TESTS FOR HURRICANE BARRIERS, WAREHAM-MARION, MASSACHUSETTS.
- (b) Division Engineer, U. S. Army Engineer Division, New England, Corps of Engineers, Waltham, Massachusetts.
- (d) Experimental; for design.
- (e) The hurricane protection plan for the area including Wareham and Marion, Mass., consists principally of 50- and 100-foot-wide, ungated barriers across the mouths of the Weweantic and Wareham Rivers, and a 100-foot-wide, gated barrier across the mouth of Onset Bay which will permit navigation during normal tides. The barriers will reduce the entry of flood surges into the waterway areas behind them during hurricanes and other severe storms. A 1:25 model, reproducing a 400-foot-wide section including 750 feet of approach channel, each navigation opening and allied barrier, and 750 feet of exit channel, was used to determine the discharge characteristics of the barriers and the maximum current velocities through the navigation openings. The cover stone of the barrier and the rock sill of each navigation opening were simulated with properly scaled model stone to provide the effect of roughness.
- (f) Completed.
- (g) Test results indicated that both free- and submerged-flow conditions can exist for tailwater elevations of C.O foot mean sea level, depending on the discharge. Therefore, the limits of each flow regime were defined, and discharge equations applicable to each were developed. A method of determining head differential based on discharge and tailwater depth for submerged flow was also developed. The measured maximum velocities were 1 to 1.5 feet per second greater than the theoretical average velocities based upon the observed head differentials.
- (h) "Discharge Characteristics of Hurricane Barriers, Wareham-Marion, Massachusetts; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-663, October 1964. (Available on loan.)
- (5241) MODEL STUDY OF WAVE ACTION AND SHIP MOORING, POINT LOMA, CALIFORNIA.
- (b) Department of the Navy.
- (d) Experimental; for design.
- (e) The Navy Electronics Laboratory desires to use an aircraft carrier, moored behind a protective breakwater about 4,000 feet offshore, in the design and development of electronic equipment. A 1:100 model reproducing about 4.5 square miles of the locality, and a 1:100 model of an Essex class aircraft carrier were used to:
- (1) Determine wave-action conditions that will obtain within the mooring area; (2) study variations in design and location of the breakwater; (3) secure data on actual movement of the model ship due to wave action; (4) investigate the feasibility of a proposed floating causeway shoreward from the ship; and (5) study adequacy of design of a proposed small-craft landing area in the immediate vicinity. Waves were generated by a 60-foot-long wave machine, and are measured and recorded electrically. The model of the aircraft carrier was dynamically balanced to reproduce the physical characteristics of the prototype ship.
- (f) Tests completed.
- (g) (1) Breakwater length was reduced from 3,600 to 2,100 feet, a 40 percent reduction from original design. (2) It was determined that wave heights behind the breakwater, and the resulting ship motion, would not be excessive insofar as waves from average severe storms are concerned. (3) The optimum crown elevation for a rubble-mound causeway and small boat landing area was established. (4) It was determined that a nearby sewer outfall pier would be unsafe for fishermen during periods when wave heights approached 13 to 18 feet because of overtopping of the structure.
- (h) Final report in preparation.
- (5242) PROTOTYPE CULVERT PRESSURE TESTS, GREENUP LOCKS AND DAM, OHIO RIVER, KENTUCKY AND OHIO.
- (b) District Engineer, U. S. Army Engineer District, Huntington, Corps of Engineers, Huntington, West Virginia.
- (d) Experimental; for design.
- (e) The filling and emptying system of the main, 110- by 1,200-foot lock consists of two culverts and a split-lateral system. Prototype pressures in this filling and emptying system and water-surface elevations in the lock chamber were measured for comparison with model results and for further development of lock design criteria. Pressures in all parts of both lock culverts, and water-surface elevations in both pools and the lock chamber were measured with electrical transducers connected to piezometers by air-purged lines. Positions of the filling and emptying valves during filling and emptying with one and both valves were determined using circular potentiometers. All data, accompanied by a common time indication, were recorded on light-beam oscillographs. Pressure data points were digitized for reduction and plotting with an electronic computer.
- (g) Tests and data reduction completed; final report will be prepared by U. S. Army Engineer District, St. Paul, Minnesota.
- (5243) PROTOTYPE TESTS, GATED INTAKE AND TUNNEL, NOLIN DAM, NOLIN RIVER, KENTUCKY.
- (b) District Engineer, U. S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.
- (d) Experimental; for design.
- (e) The Nolin Dam outlet works consist of a three-gated intake structure and horseshoe-shaped tunnel having a capacity of 16,000 cubic feet per second. Tests were conducted to measure the tunnel hydraulic grade line and gate-hoist cylinder pressures; from these measurements tunnel friction and intake losses are being evaluated and gate forces computed. Test facilities included five pairs of sidewall piezometers connected to a manifold. Pressures at full tunnel flow were measured by means of the air-purge technique, using a mercury manometer and a pressure gage. Pressure taps were provided in one of the operating gate-hoist cylinders and measurements of gate hydraulic cylinder pressures were made with pressure gages.
- (g) Tests indicated lower friction than had been assumed in design of the outlet works tunnel.
- (5245) MODEL STUDY OF HOUSTON SHIP CHANNEL, TEXAS.
- (b) District Engineer, U. S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.

- (d) Experimental; for design.
 - (e) Houston Ship Channel is a 52-mile reach extending from the Gulf of Mexico across Galveston Bay to the Turning Basin at Houston. A model study is being conducted to determine if the present cost of maintenance dredging in the channel can be reduced by proposed plans of channel realignment, partial or complete diking of connecting bays, sediment traps, dikes in Galveston Bay, local contractions, enlargements, and other remedial measures. The model reproduces a portion of the Gulf of Mexico outside the entrance to Galveston Bay; all of Galveston and Trinity Bays; Dickinson Bay and Clear Creek to the head of project; the tidal portion of Trinity River; the Houston Ship Channel in its entirety; and Buffalo Bayou from the Turning Basin to the confluence of White Oak Bayou. The model is of fixed-bed construction with scale ratios, model to prototype, of 1:600 horizontally and 1:60 vertically. Tides and tidal currents are reproduced by a tide generator located in the Gulf of Mexico portion of the model, and the salinity of the model Gulf is reproduced to scale so that the effects of salinity differences on the vertical distribution of current velocities, as well as salinity concentrations throughout the model, accurately reproduce those of the prototype. The model will be used to establish the effects of all proposed improvement works on tidal current velocities, current patterns, and salinities in all critical areas. All hydraulic and salinity data obtained from the model will be quantitative and can be applied directly to the prototype. Shoaling studies will be made by injecting finely ground gilsonite into the model to reproduce the patterns of shoaling as observed in the prototype, following which the effects of proposed improvement plans on shoaling patterns may be observed and evaluated from a qualitative viewpoint.
- (5246) MODEL STUDY OF NAVIGATION CONDITIONS, UNIONTOWN LOCK AND DAM, OHIO RIVER.
- (b) District Engineer, U. S. Army Engineer Dist., Louisville, Corps of Engineers, Louisville, Kentucky.
 - (d) Experimental; for design.
 - (e) The project includes a nonnavigable, gated structure and two parallel locks. A 1:120 model, reproducing about 8.6 miles of the Ohio River and adjacent overbank areas, the lock and dam structures, and the lower reach of the Wabash River, is being used to investigate navigation conditions with the proposed structures, to determine the effects of modifications in the composition and arrangement of the structures, and to develop any modifications considered desirable.
 - (g) Tests indicated the need for modification in composition and arrangement of the locks and dam structures, and developed information needed for design.
- (5247) MODEL STUDY OF FILLING AND EMPTYING SYSTEM, JONESVILLE LOCK AND DAM, OUACHITA-BLACK RIVER, LOUISIANA.
- (b) District Engineer, U. S. Army Engineer District, Vicksburg, Corps of Engineers, Vicksburg, Mississippi.
 - (d) Experimental; for design.
 - (e) A 1:25 model, reproducing 750 feet of the lock approach channel, intake manifold, the 84-by 600-foot lock chamber, culvert, sidewall port manifolds, outlets, and 650 feet of the exit channel, is being used to develop the optimum side port filling and emptying system for the lock.
 - (f) Tests completed.
 - (g) None of the port arrangements using 22-foot spacing resulted in operating characteristics as favorable as those obtained in earlier tests with the types 3 and 19 port arrangements which used a 20-foot spacing.
- (h) Final report in preparation.
- (5248) MODEL STUDY OF FLOATING BREAKWATER, SMALL BOAT BASIN NO. 2, JUNEAU, ALASKA.
- (b) District Engineer, U. S. Army Engineer District, Alaska, Corps of Engineers, Anchorage, Alaska.
 - (d) Experimental; for design.
 - (e) A floating-log breakwater is proposed to protect Small Boat Basin No. 2 from storm-wave action. To determine wave attenuation characteristics of a floating-log breakwater, tests were conducted in a concrete wave flume 119 feet long, 5 feet wide, and 4 feet deep. Models of a 30-foot-long section of the breakwater were reproduced at a linear scale of 1:6. The breakwaters simulated 3- and 4-foot-diameter logs spaced on 4.0-, 5.7-, and 8.2-foot centers. Vertical barrier plates were attached to the faces of the logs to increase the effective depth of flotation of the logs. Model waves were generated by a plunger-type wave machine, and measured and recorded electrically.
 - (f) Completed.
 - (g) It was found that 3-foot-diameter logs spaced from 5.5 to 6.0 feet on centers would provide sufficient protection to the boat basin, based on the criterion of a transmitted wave height (H_T) \leq 0.5 foot, if it is considered feasible to add vertical plates to the seaside face of the logs extending to a depth of 4 feet below the stillwater level.
 - (h) "Twin-Log Floating Breakwater, Small-Boat Basin No. 2, Juneau, Alaska; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Miscellaneous Paper No. 2-648, May 1964. (Available on loan.)
- (5249) PROTOTYPE HAWSER-STRESS MEASUREMENTS, JACKSON LOCK, TOMBIGEE RIVER, ALABAMA.
- (b) District Engineer, U. S. Army Engineer District, Mobile, Corps of Engineers, Mobile, Alabama, and Office, Chief of Engineers, Washington, D. C.
 - (d) Experimental; for design.
 - (e) The Jackson Lock chamber is 110 feet wide by 670 feet long and has a 34-foot maximum lift. Reverse tainter valves control flow in two 12.5-foot-square culverts, each of which has 6 intake ports in the upper approach walls, 14 side ports to the lock chamber, and an outlet discharging outside the lower lock approach. Measurements of prototype hawser loads resulting from hydraulic forces acting on a tow of loaded barges were made to obtain data for comparison with model test results. Both rigid and flexible connections between the tow and floating mooring bitts were used in the tests. The rigid connections, containing calibrated dynamometers, were installed fore and aft on the portside of the tow and connected to floating mooring bitts in the lock land wall. One connection measured longitudinal hawser forces, and the other measured transverse forces. Potentiometers were mounted on the culvert-valve operating arm to measure valve opening. Differential-type pressure transducers were used for measuring the slope of the water surface in the lock chamber, and absolute pressure transducers were used for drawdown measurements of the water surface in the approach channel. Potentiometers also were installed on the land-wall floating bitts to measure tow movement during the rigid connection tests. For the flexible-connection tests, the rigid connections were replaced by flexible hawsers of 1-inch-diameter wire rope, and calibrated dynamometers were installed in the hawsers at each corner of the tow and connected to floating bitts in both lock walls. Other instrumentation was identical with that of the rigid connection

- tests.
- (h) Final report in preparation.
- (5250) PROTOTYPE SPILLWAY TESTS, FORT RANDALL DAM, MISSOURI RIVER, SOUTH DAKOTA.
- (b) District Engineer, U. S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska.
- (d) Experimental; for design.
- (e) The Fort Randall Dam spillway is a 1,000-foot-wide concrete chute, with a design capacity of 620,000 cubic feet per second. Discharge is controlled by twenty-one 29- by 40-foot tainter gates. Two test series, one in 1960 and one in 1962, have been conducted to obtain vertical velocity distribution and water-surface depths on the spillway chute for use in checking design resistance coefficient assumptions and computing discharge over the spillway. These data will assist in eliminating a deficiency in the information on full-scale chute spillway flows used in design of such structures. To obtain the measurements, two pitot piers were fabricated and installed on the spillway chute. The pitot piers instrumentation consisted of eight total-head tubes to measure vertical velocity distributions. Water-surface measurements along the spillway length were made with wire-weight gages. Visual observations and photographic records of flow conditions were also made. Data were obtained at seven average flow depths up to 3.5 feet with velocities up to 45 feet per second.
- (h) Final report in preparation.
- (5251) MODEL STUDY OF NAVIGATION CONDITIONS, ROBERT S. KERR LOCK AND DAM, ARKANSAS RIVER.
- (b) District Engineer, U. S. Army Engineer District, Tulsa, Corps of Engineers, Tulsa, Oklahoma.
- (d) Experimental; for design.
- (e) The project will consist of a nonnavigable dam, a 110- by 600-foot lock, and a powerhouse. A 1:120 model, reproducing about 3.2 miles of the Arkansas River and the lock and dam structures, is being used to study navigation conditions in the approaches to the lock, determine suitability of the selected site, and develop modifications required to overcome any undesirable conditions. The model will be of the fixed-bed type with provision for a movable-bed section below the dam for use in developing channel configurations in the reach.
- (g) Tests resulted in the development of anticipated channel configurations downstream of the dam and modifications which would provide satisfactory navigation conditions in the approaches to the lock.
- (5634) MODEL STUDY OF BREAKWATERS, DANA POINT HARBOR, CALIFORNIA.
- (b) District Engineer, U. S. Army Engineer District, Los Angeles, Corps of Engineers, Los Angeles, California.
- (d) Experimental; for design.
- (e) Dana Point Harbor is a proposed small-craft harbor to be constructed at a site which is exposed to ocean waves. The harbor will be protected by rubble-mound breakwaters which will allow some of the wave energy to pass through the structure. Tests to determine (1) the effectiveness of the proposed breakwater sections in reducing transmitted wave energy and (2) the stability of the breakwaters were conducted to provide a basis for the design of the proposed harbor, and to add to the available basic data on the transmission of wave action into artificial harbors. Section models of the proposed structures, constructed to linear scales of 1:50 and 1:100, were tested in a concrete flume 119 feet long, 5 feet wide, and 4 feet deep. Model waves were generated by a plunger-type wave machine and measured and recorded electrically.
- (g) Stability tests showed that the proposed breakwater section would be adequate to withstand the attack of the 12-second, 16-foot design waves. The maximum transmitted wave height measured on the harborside was found to be about 45 percent of the incident wave height. The average value of the wave transmission coefficient (H_r/H_i) was about 15 percent. The longer the wave period, the more wave energy was transmitted through a rubble-mound breakwater. Appreciable scale effect in wave transmission was found between the results of tests obtained from the 1:50- and 1:100-scale model.
- (5635) INVESTIGATION OF WAVE REFLECTING AND TRANSMITTING CHARACTERISTICS OF RUBBLE-MOUND BREAKWATERS, RUBBLE-WAVE ABSORBERS, SAND BEACHES, WAVE TRAPS, AND RESONATORS.
- (b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.
- (d) Experimental; applied research.
- (e) A theoretical study is being conducted to evaluate the advantages and disadvantages of different types of wave absorbers and to establish a sound basis for laboratory tests of the wave reflecting and transmitting characteristics of rubble breakwaters and wave reflecting-absorbing characteristics of the different types of wave absorbers. The scale effects relating to wave absorbers will be investigated. Laboratory investigations of the different types of absorbers and the wave reflecting transmission characteristics of rubble breakwaters will be conducted in three wave flumes, a 1- by 1.5- by 85-foot tank, a 5- by 4- by 119-foot tank, and a 2- by 5.5- by 149-foot tank.
- (5636) MODEL STUDY OF FLUSHING SYSTEM, VICTORIA CHANNEL, TEXAS.
- (b) District Engineer, U. S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.
- (d) Experimental; for design.
- (e) Victoria Channel will extend about 35 miles from the Gulf Intracoastal Waterway to a turning basin near Victoria, Tex. A flushing system for the channel is proposed to eliminate surface debris, oil, and foul water. Tests to determine the flow requirements of the flushing system to replace the stagnant water in the navigation channel were made in the Waterways Experiment Station salinity flume which is 327 feet long, 0.75 foot wide, and 1.5 feet deep. Duplicate tests were made for two depth scales (1:15 and 1:30) to determine if the data contained any significant scale effects. In both series of tests, the horizontal scale for length along the channel was 1:323, and that for width across the channel was 1:173. Use of different horizontal scales for length and width was necessary to make the existing flume dimensions conform to those of the landlocked portion of the channel. The salinity scale used for the tests was 1:1.
- (f) Tests completed.
- (g) With the design discharge of 1,000 cubic feet per second, the 20-mile-long landlocked reach of the channel was 50 percent flushed in about 17 hours, 75 percent flushed in about 29 hours, and 100 percent flushed in about 60 hours. With a lesser discharge (500 cubic feet per second), the channel was 50 percent flushed in about 38 hours, and 75 percent flushed in about 60 hours. The test data also showed that the surface stratum of the channel would be completely flushed in 22 hours with a discharge of 1,000 cubic feet per second, or in 35 hours with a discharge of 500 cubic feet per second.
- (h) Final report in preparation.
- (5637) SECTION MODEL OF BELLEVILLE DAM SPILLWAY,

OHIO RIVER, WEST VIRGINIA.

- (b) District Engineer, U. S. Army Engineer District, Huntington, Corps of Engineers, Huntington, West Virginia.
 - (d) Experimental; for design.
 - (e) Belleville Dam spillway will consist of a concrete sill surmounted by eight tainter gates, and a conventional horizontal stilling basin with baffle piers and end sill. A 1:36 model, reproducing approximately 700 feet of the approach area, one central gate bay and approximately one-half of the adjacent bays as well as the piers that separate them, a 216-foot-wide section of the stilling basin, and approximately 800 feet of the exit area, was used to determine the optimum shape for the downstream face of the gate sill, develop a satisfactory stilling basin, and verify the stability of the riprap blanket proposed downstream from the stilling basin.
 - (f) Tests completed.
 - (g) The original parabolic gate sill shape functioned satisfactorily. The stilling basin as originally designed produced maximum bottom velocities in the exit channel as high as 27.0 feet per second. However, a basin was developed that reduced these velocities to 15 feet per second. A riprap stability curve was determined with the stone placed on a 1-on-6 slope downstream of the stilling basin.
 - (h) Final report in preparation.
- (5638) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 9, ARKANSAS RIVER.
- (b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
 - (d) Experimental; for design.
 - (e) The structures will consist of a gated dam (60-foot span), and a 110- by 600-foot lock with a maximum lift of 19 feet. A 1:120 model, reproducing about 6 miles of the Arkansas River and adjacent overbank area near Morrilton, Ark., will be used to investigate navigation conditions with the proposed structures, to determine the effects of modifications in the composition and arrangement of the structures, and to develop such modifications as might be considered desirable. The model will be of the fixed-bed type with provisions for changes in the channel based on the effects of the proposed regulating structures.
- (5639) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 7, ARKANSAS RIVER.
- (b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
 - (d) Experimental; for design.
 - (e) A 1:120, fixed-bed, comprehensive model, reproducing about 7 miles of the Arkansas River, adjacent overbank areas, the lock (110 by 600 feet) and dam structures, and other structures that might affect flow conditions, will be used to study navigation conditions in the lock approaches, the design of the upstream guard wall, and location and design of any training works needed to improve navigation conditions and distribution of flow to the spillway.
- (5640) MODEL STUDY OF POLLUTION DISPERSION, CHARLESTON HARBOR, SOUTH CAROLINA.
- (b) District Engineer, U. S. Army Engineer District, Charleston, Corps of Engineers, Charleston, South Carolina.
 - (d) Experimental; for design.
 - (e) A fixed-bed model, constructed to scales of 1:100 vertically and 1:2000 horizontally, will be used to provide data on dispersion and transport of wastes in Charleston Harbor under various conditions of freshwater inflow along with data on tides, currents, and salinities for all inflow conditions studied.

The model reproduces about 17 miles of shoreline, 230 square miles of the Atlantic Ocean, and the entire tidal portions of the Cooper, Ashley, and Wando Rivers and their tributaries. Provisions are included for reproducing tides and tidal currents, upland freshwater flows, ocean salinities, and salinity intrusion. Conservative-type fluorescent dyes will be introduced to simulate industrial and municipal waste.

- (5641) MODEL STUDY OF DROP STRUCTURE, SANDUSKY RIVER, FREMONT, OHIO.
- (b) District Engineer, U. S. Army Engineer District, Buffalo, Corps of Engineers, Buffalo, New York.
 - (d) Experimental; for design.
 - (e) Improvement of the Sandusky River channel will include a drop structure near the upper end of the improved reach to dissipate energy created by the difference in water-surface elevations above and through the reach. The structure will include a 10-foot-high weir, stilling basin, and riprap protection above and below the weir. A 1:36 model, reproducing the drop structure and 800 feet of the channel upstream and 900 feet downstream, will be used to develop an economical design of the drop structure which will assure the dissipation of the kinetic energy developed when the water-surface profile drops from existing levels upstream to the levels within the improved channel.
 - (g) While the original design drop structure performed satisfactorily, basin tests indicated an increased basin length (19 feet) would improve energy dissipation of the structure. Twelve 3- by 20-foot openings through the structure provided satisfactory fish-passage facilities.
- (5642) MODEL STUDY OF SMALL BOAT HARBOR, DANA POINT, CALIFORNIA.
- (b) District Engineer, U. S. Army Engineer District, Los Angeles, Corps of Engineers, Los Angeles, California.
 - (d) Experimental; for design.
 - (e) The inner-harbor berthing area and navigation channels will comprise about 200 acres. The inner-harbor basin will be enclosed by a mole and will be accessible through 200-foot-wide navigation entrances, one at each end of the 3,500-foot-long inner basin. The inner harbor will be protected by two arms of rubble-mound breakwater having a total length of about 7,700 feet. Tests to study the effects of storm-wave action on the proposed harbor design and to determine what, if any, design modifications are necessary to ensure that wave heights during storms do not exceed (1) 1.5 feet in the inner-basin anchorage, (2) 4 feet in the approaches to the entrances of the inner-harbor berthing areas, (3) 5 feet in the fairway channel paralleling the proposed west breakwater, and (4) 2.5 feet in the ramp basin area in the eastern sector of the inner harbor, are being conducted on a 1:100, fixed-bed model. The model reproduces sufficient area of the shoreline and oceanward to ensure that propagation of waves toward the problem area is adequately simulated. Waves are generated by a 60-foot-long, plunger-type wave machine, and are measured and recorded electrically.
- (5643) ACOUSTIC FLOWMETER INSTALLATION AND PROTOTYPE TESTS OF OUTLET WORKS, SUMMERSVILLE DAM, GAULEY RIVER, WEST VIRGINIA.
- (b) District Engineer, U. S. Army Engineer District, Galveston, Corps of Engineers, Huntington, West Virginia.
 - (d) Experimental; field investigation.
 - (e) The outlet works consist of an intake structure, 29-foot-diameter operating tunnel,

- three 11-foot-diameter outlet conduits, and one 3-foot-diameter low-flow outlet pipe. Tests will be made with an acoustic flowmeter to gage operational discharges, and to measure pressure gradients through the three-branch manifold connecting the 29-foot tunnel to the three 11-foot conduits; from these measurements, evaluations of tunnel resistance and intake and manifold losses will be made. The acoustic flowmeter includes a pair of transducers in the tunnel and each conduit and the accompanying circuitry to indicate the discharge from the effects of the flow rates on the acoustic signals. The pressure test facilities consist of six pairs of piezometers along the tunnel and three pairs along each conduit.
- (g) A Westinghouse LE (leading-edge) acoustic flowmeter was installed in a power penstock at Oahe Dam for evaluation tests. Comparative discharge measurements included acoustic, pressure-momentum (Gibson), Winter-Kennedy flowmeter, dye dilution, volumetric changes in the surge tanks, and the turbine model tests. Preliminary analyses of the test data indicate that the acoustic flowmeter measurements should be as accurate as any of the measurements with which they were compared.
- (5644) MODEL STUDY OF NAVIGATION CONDITIONS IN THE LITTLE ROCK REACH, ARKANSAS RIVER.
- (b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
- (d) Experimental; for design.
- (e) A fixed-bed model reproducing about 3 miles of the Arkansas River and adjacent overflow areas to a scale of 1:100, is being used to study navigation conditions through six bridges at Little Rock, Ark., to determine modifications required in the existing bridges, and to develop a plan of regulating structures required to provide satisfactory navigation conditions.
- (g) Results indicate that navigation conditions with existing conditions would be hazardous due to alignment of the navigation spans, limited width of span, and limited distance between bridges.
- (5645) MODEL STUDY OF OUTLET WORKS, COCHITI DAM, NEW MEXICO.
- (b) District Engineer, U. S. Army Engineer District, Albuquerque, Corps of Engineers, Albuquerque, New Mexico.
- (d) Experimental; for design.
- (e) The dam will contain a concrete, gravity, uncontrolled spillway with a 460-foot-long ogee crest. A 160-foot-long section of the spillway crest will be lowered 10.5 feet to provide a service spillway. The outlet works will consist of a triple box conduit. The necessity for providing a reliable water supply for irrigation throughout the range of conduit releases, and the need for a two-level stilling basin 60 feet wide to provide for flows as large as 15,200 cfs made it desirable to test the energy dissipator, and the irrigation and silt sluices in a model. Tests were conducted in a 1:20 model that reproduced the downstream 150 feet of the triple box conduit, the chute, the primary and secondary stilling basins, the irrigation and the silt sluices, and 670 feet of exit channel.
- (f) Tests completed.
- (g) Primary and secondary stilling basins, requiring elements of minimum size at the optimum locations, were developed. The secondary stilling basin, which used tailwater to aid in hydraulic-jump formation, was raised 5 ft. The irrigation sluices were calibrated over the anticipated range of flows. Qualitative silt removal tests of the primary basin were conducted.
- (h) Final report in preparation.
- (5646) SECTION MODEL OF SPILLWAY, HANNIBAL DAM, OHIO RIVER.
- (b) District Engineer, U. S. Army Engineer District, Pittsburgh, Corps of Engineers, Pittsburgh, Pennsylvania.
- (d) Experimental; for design.
- (e) The spillway will consist of a concrete sill surmounted by 8 tainter gates and a conventional, horizontal stilling basin with baffle piers and end sill. A 1:36 section model, reproducing approximately 700 feet of the approach area, one central gate bay and the adjacent half-bays of the spillway, a 216-foot-wide section of the stilling basin, and approximately 800 feet of the exit area, will be used to investigate the adequacy of the proposed stilling basin for a full range of tailwater elevations at which the structure will be required to operate.
- (5647) GATE VIBRATION TESTS.
- (b) Office of the Chief of Engineers, Department of the Army, Washington, D. C.
- (d) Experimental; applied research.
- (e) A systematic-laboratory investigation will be made to provide design criteria to eliminate or mitigate vibration phenomena at gates and operating criteria for various gate geometrics and conduit configurations with particular attention to the prediction of critical gate opening and operating head combinations. The study will be performed in a 0.5- by 2-foot water tunnel and an 0.5- by 2-foot conduit connected to a head tank. The flow velocity in the water tunnel is continuously controlled by a fluid drive up to a maximum of 35 feet per second and the ambient pressure in the low-velocity section can be varied from -9 to 20 pounds per square inch gage. The maximum velocity in the conduit is 7 feet per second. Tunnel and face-type gates of various thicknesses and shapes will be installed and studied.
- (5648) MODEL STUDY OF SHOALING, BRUNSWICK HARBOR, GEORGIA.
- (b) District Engineer, U. S. Army Engineer District, Savannah, Corps of Engineers, Savannah, Georgia.
- (d) Experimental; for design.
- (e) A fixed-bed model, constructed to scales of 1:100 vertically and 1:500 horizontally and reproducing the harbor, tributary rivers and creeks, and East River in its entirety, will be used to determine if the present high rate of shoaling in East River can be reduced by either changing the distributions of flows, creating turbulence, increasing bottom velocities, or by reducing the tidal prism of East River to a minimum. Automatic tide generators will reproduce tides and tidal currents throughout the harbor. Shoaling studies will be made by injecting finely ground gilsonite into the model to reproduce the patterns of shoaling observed in the prototype, and to determine the effects of proposed improvement plans on shoaling patterns. Changes in shoaling patterns as effected by each proposed improvement plan will be determined and evaluated.
- (5649) SECTION MODEL OF SPILLWAY, CANNELTON DAM, OHIO RIVER, INDIANA.
- (b) District Engineer, U. S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.
- (d) Experimental; for design.
- (e) The spillway will consist of a concrete sill surmounted by 12 tainter gates and a conventional horizontal stilling basin with baffle piers and end sill. A riprap blanket will be provided downstream from the stilling basin to prevent undermining of the structure. A 1:36 section model, reproducing approximately 70 feet of the approach area, one central gate bay and adjacent half bays of the spillway, a 216-foot-wide section of the stilling basin, and approximately 800 feet of the exit area, is being used to determine the

flow characteristics of the spillway, the optimum elevation and configurations of the apron, baffle piers, and end sill, and to develop an adequate protective stone blanket downstream from the stilling basin.

- (g) A parabolic weir crest upstream of the gate seals was found to provide satisfactory flow characteristics with the submergible-type tainter gates, and a parabolic gate sill downstream of the gate seals was found to be desirable with the nonsubmergible-type tainter gates. A satisfactory stilling basin and protective stone blanket were developed for each design.
- (5650) MODEL STUDY OF FILLING AND EMPTYING SYSTEM, CORDELL HULL LOCK, CUMBERLAND RIVER, TENN.
 - (b) District Engineer, U. S. Army Engineer District, Nashville, Corps of Engineers, Nashville, Tennessee.
 - (d) Experimental; for design.
 - (e) The lock will be 84 by 400 feet. A 1:25 model, reproducing only the portion of the lock between filling and emptying valves, is being used to evaluate the overall performance of the multiport system, with particular emphasis on determining the optimum number and position of chamber ports, and to investigate methods of controlling pressures below the filling valves.
 - (g) Tests confirmed that acceptable performance could be expected from the original design multiport arrangement. Additional tests resulted in the development of satisfactory multiport arrangements using 8-, 10-, and 12-inch-diameter ports. For a lift of 62 feet, these arrangements resulted in a filling time of about 8.9 minutes with a maximum hawser stress of about 3.5 tons. Tests indicated that pressure conditions in the critical area just downstream from the filling valve were improved by flaring the culvert roof at the downstream end of the valve well. The effect of air venting on culvert pressures was also investigated.
- (5651) MODEL STUDY OF JAMES RIVER, VIRGINIA.
 - (b) District Engineer, U. S. Army Engineer District, Norfolk, Corps of Engineers, Norfolk, Virginia, and the State of Virginia.
 - (d) Experimental; for design.
 - (e) The James River, which discharges into Chesapeake Bay, presently has a controlling channel depth from Newport News to Richmond of 25 feet mean low water. An improvement plan has been proposed to increase the channel depth to 35 feet mean low water, and widen the channel at several locations. Because the James River estuary and tributaries provide ideal locations for oyster beds, an important industry in the area, a model study will be made to determine the effects of the channel improvements on hydraulic and salinity conditions in and adjacent to the oyster beds. The fixed-bed model will reproduce 300 square miles of the Atlantic Ocean, the James River estuary, and all its principal tributaries from Norfolk to Richmond, Va., to scales of 1:1,000 horizontally and 1:100 vertically. Tides and tidal currents will be reproduced by a tide generator located in the ocean portion of the model. The ocean salinity will be reproduced so that the effects of salinity differences on the vertical distribution of current velocities, as well as salinity concentrations throughout the model, will accurately simulate those of the prototype.
- (5652) MODEL STUDY OF NAVIGATION CONDITIONS, WEBBERS FALLS LOCK AND DAM, ARKANSAS RIVER.
 - (b) District Engineer, U. S. Army Engineer District, Tulsa, Corps of Engineers, Tulsa, Oklahoma.
 - (d) Experimental; for design.
 - (e) A fixed-bed, 1:120 model will be used to study navigation conditions in the approaches to the lock, determine the adequacy of the design, and develop modifications required to overcome any undesirable conditions. The model will reproduce about 3.1 miles of the Arkansas River and the lock and dam structures.
- (5653) MODEL STUDY OF LAKE ERIE-LAKE ONTARIO WATERWAY.
 - (b) District Engineer, U. S. Army Engr. District, Buffalo, Corps of Engineers, Buffalo, N. Y.
 - (d) Experimental; for design.
 - (e) The project will provide a second overland navigation canal from Lake Erie to Lake Ontario to supplement the existing Welland Canal. An existing fixed-bed model, constructed to scale ratios of 1:360 horizontally and 1:60 vertically, and reproducing the Niagara River from Buffalo to Rainbow Bridge below the Falls, will be used to investigate control structure and lock arrangements, and navigation channel features including compensating excavations or structures required to maintain existing stage-discharge relations. Navigation conditions at the entrance to the overland canal will be studied in a second model.

H. G. ACRES & COMPANY LIMITED, Hydraulic Laboratory.

Inquiries concerning the following projects should be addressed to Mr. O. M. Erickson, Head, Hydraulic Department, H. G. Acres & Company Limited, Consulting Engineers, Niagara Falls, Canada.

(5088) MODEL TESTS OF CHUTE SPILLWAY FOR THE CALIMA II HYDRO-ELECTRIC PROJECT.

- (b) Corporacion Autonoma Regional Del Cauca, Cali, Colombia.
- (d) Experimental; design.
- (e) Tests were performed on a 1:32.8 scale movable bed model to determine the approach conditions which provided the optimum discharge characteristics for the ogee shaped spillway which is constructed on an arc, the freeboard requirements and the magnitude and frequency of pressure fluctuations on the 240-metre long chute which drops 46 metres, and the optimum shape of the downstream flip bucket.
- (f) Tests completed.
- (h) Report submitted to client.

(5616) MODEL TESTS OF THE PERMANENT RIVER DIVERSION STRUCTURE FOR THE CALIMA II HYDRO-ELECTRIC PROJECT.

- (b) Corporacion Autonoma Regional Del Cauca, Cali, Colombia.
- (d) Experimental; design.
- (e) The powerhouse for the Calima II Hydro-Electric Project will be constructed across the yoke of an ox-bow of the Calima River. The tailrace will discharge at right angles to the river flowing through the permanent diversion channel. Model tests were carried out on a 1:32.8 scale movable bed model of the tailrace and diversion channel to determine the optimum geometry of the intake to the channel, and the configuration of the tailrace weir and channel slope to eliminate flooding of the powerhouse under design flood conditions.
- (f) Tests completed.
- (g) Report submitted to client.

(5617) MANICOUAGAN II SPILLWAY CHANNEL.

- (b) Hydro-Quebec.
- (d) Experimental; design.
- (e) The discharge of 200,000 cfs, leaving the flip bucket of the spillway, has to be conducted over a rock slope and back into the river downstream of the powerhouse. A model of the spillway, including the five gates and the topography of the slope and riverbed, is being built to a scale of 1:72. Tests will determine the most economical excavated channel and wall combination. The movement of loose rock in the riverbed and its effect on the powerhouse discharge will also be studied.

(5618) MODEL TESTS OF THE ROCKFILL CAUSEWAY CROSS SECTION FOR THE NORTHUMBERLAND STRAIT CROSSING.

- (b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
- (d) Experimental; design.
- (e) The rockfill causeway section of the Northumberland Strait Crossing will be approximately three miles in length. The rockfill core must be protected against the combined effects of a 20-foot design wave, currents resulting from partial closure of the Strait which at present experiences 8-foot tides, and the movement of extremely large ice floes. Wave studies are being carried out on a 1:20 scale model to determine the most economic combination of dyke freeboard, dyke slope, primary pre-cast concrete armour units and secondary riprap requirements, which will meet the design conditions.

(5619) TIDAL MODEL TESTS FOR THE PROPOSED NORTHUMBERLAND STRAIT CROSSING.

- (b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
- (d) Experimental; design.
- (e) To study the effect of partial closure of the Northumberland Strait by the building of a causeway. Model studies are being made of the Strait to scale of 1:6400 horizontal and 1:64 vertical. Tidal movements within the Strait are caused by the tides imposed on the entrances; two tide generators are therefore used. The principal objectives of the study are to confirm conclusions derived from analytical calculations, to determine the velocity distribution through the causeway opening, the overall velocity pattern, and the maximum tidal difference across the causeway. On completion of the studies for design data, the model will be available for studies required by other interested agencies such as the Department of Fisheries.

(5620) MODEL STUDY OF BRIDGE PIERS SUBJECTED TO PRESSURES FROM LARGE ICE FLOES.

- (b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
- (d) Experimental; design.
- (e) Piers for the bridged section of the proposed crossing of Northumberland Strait will be subjected to ice pressure. Various shapes are being tested on a 1:60 scale model to find the magnitude and direction of the forces, and to observe the mechanics of the splitting and breaking of ice floes against these piers. A special substance has been devised having the appropriate mechanical properties to simulate the ice to the scale of the model. The piers are supported by a specially designed dynamometer and placed in the centre of a raceway. The artificial ice floes, floating in the water, are either carried by the current of water, or forcibly propelled and made to collide with the pier.

(5621) PANELS FOR MEASUREMENT OF ICE PRESSURES AT PORT BORDEN, PRINCE EDWARD ISLAND.

- (b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
- (d) Field investigation; design.
- (e) A study to determine the forces exerted by a large ice floe when driven by strong winds against the end of a pier at Port Borden. The measurements are to be made by means of a pair of hollow steel panels with relatively flexible walls which are supported on the vertical faces of the pier. On being subjected to ice pressures, the walls of the panels transmit the forces to a number of hydraulic flat jacks placed inside them. By sensing the pressure of the hydraulic fluid in the jacks, oscillographs will be obtained of the forces exerted by the ice at various elevations and for both long and short periods of time.

UNIVERSITY OF BRITISH COLUMBIA, Hydraulics Lab.

(4451) HEAD LOSS IN SPHERICAL AND CONVENTIONAL WYES.

- (b) Laboratory project.
- (c) Dr. E. Ruus, Dept. of Civil Engineering, University of British Columbia.
- (d) Applied research. Much of the experimental work is being done by an M.A.Sc. student.
- (e) The spherical wye due to its small dimensions is particularly suitable as a wye-branch in large penstocks under high head. A Lucite model of a spherical wye was constructed and the head losses measured. Models for conventional type of wyes are under construction. For all wyes the inside diameter of the main pipe and the branch pipes are 5 1/4 and 3 3/4 inches respectively.

Several modifications such as tapered outlets, rounded corners and different sphere diameters are being investigated.

- (f) Continued.
- (4902) FLOOD SYNTHESIS AND FORECASTING FOR THE FRASER RIVER.
- (b) British Columbia Disaster Relief Fund Committee.
- (c) Dr. M. C. Quick, Dept. of Civil Engineering.
- (d) Mainly theoretical, using existing meteorological and hydrological data, but some extra field and laboratory work is being undertaken.
- (e) Starting with meteorological data, an attempt has been made to synthesise the 1948 Fraser Flood. Data for other peak flow years has also been examined. From this study a method is being developed to assess the probability of certain peak flows. The present experimental project is concerned with soil temperature gradients and freezing levels under the snow.
- (h) Preliminary report. Paper ready for publication.
- (4903) FORCES ENCOUNTERED BY A CYLINDER IMMERSED IN FLOWING WATER.
- (b) Laboratory project.
- (c) Dr. M. C. Quick, Dept. of Civil Engineering, Univ. of British Columbia.
- (d) Experimental and theoretical; basic research. Much of the experimental work is being done by an M.A.Sc. student.
- (e) The main purpose is to study the variation of lateral and drag forces with the permitted amplitudes of vibration of the cylinder. Various methods of stabilizing the cylinder to reduce or remove the oscillating forces, are being investigated.
- (f) Investigation continuing.
- (h) M.A.Sc. Thesis by Yu Min Chow, April 1964.
- (4904) FISH PASSAGE THROUGH HYDRAULIC TURBINES - INFLUENCE OF INJECTION OF COMPRESSED AIR ON FISH MORTALITY.
- (b) Laboratory project.
- (c) Dr. E. Ruus, Dept. of Civil Engineering, Univ. of British Columbia.
- (d) Experimental; applied research. Much of the experimental work is being done by an M.A.Sc. student.
- (e) Cavitation is considered as a major factor contributing to the mortality of fish passing through a hydraulic turbine. Injection of compressed air in the regions of maximum cavitation results in a significant reduction in cavitation. This project is being undertaken to determine the extent of reduction in fish mortality resulting from the injection of compressed air into the penstock or draft tube. In a series of tests young salmon will be injected into the penstock and will pass through a 10 in. dia. four-bladed model propeller wheel. The turbine will operate under different conditions of speed, gate opening and sigma.
- (f) Continued.
- (h) M.A.Sc. Thesis by Thamrong Prempridi, Sept. 1964.

ECOLE POLYTECHNIQUE, Department of Civil Engineering, Hydrodynamics Laboratory.

- (4043) STUDY OF THE RELIABILITY AND OPERATION OF BACK-WATER VALVES ON PLUMBING SYSTEMS AGAINST FLOODING BY PUBLIC SEWERS.
- (b) City of Montreal, City Planning Department, Inspection Division.
- (c) Professor Raymond Boucher, Director, Hydrodynamics Laboratory, Ecole Polytechnique, 2500 Marie-Guyard Avenue, Montreal 26, Quebec, Canada.
- (d) Experimental; applied research.

- (e) A full scale three-story plumbing system has been erected in the Hydrodynamics Laboratory of Ecole Polytechnique. The diameter of the pluvial column, the soil stack and the drain is 4 inches. The drain has many sections of pyrex glass to permit observations at critical points. A system of valves and of cross-connections on the vents leads to various combinations of tests. The back-water valves have a transparent lucite cover to enable visual observations. As air entrainment has a great importance on the venting capacity, the rate of air entrained in the vertical columns is measured at the inlet by means of a hot-wire air-meter. Various flooding conditions of the public sewers are simulated by a tank in which the water level can be controlled by gate valves. This research is aimed at determining whether back-water valves can offer home dwellers a reliable protection against flooding due to any overload of combined sewers. If this method is not satisfactory, an improved design of plumbing system may be suggested.
- (f) Temporarily suspended.
- (g) The mechanism of air entrainment has been studied and tests have revealed the best position for some of the vents.
- (h) Interim report entitled "Etude experimentale des soupapes de surete contre les surcharges d'egout", by Andre Leclerc, Roger Labonte and Raymond Boucher, December 1963, submitted to sponsor.
- (5089) MODEL TESTS OF THE PILLUR DAM SCOUR VENT FOR THE KUNDAL HYDRO-ELECTRIC PROJECT, INDIA.
- (b) Canadian Vickers Limited.
- (c) Professor Raymond Boucher, Director, Hydrodynamics Laboratory, Ecole Polytechnique, 2500 Marie-Guyard Ave., Montreal 26, Quebec, Canada.
- (d) Experimental; applied research.
- (e) The purpose of the investigation was to study the hydraulic performance of a scour vent for different headwater and tailwater conditions. The model built to a scale of 1:20 comprises a hydraulic inlet flared in three directions, a vertical lift emergency gate, a radial type control gate and an energy dissipator. The experimental investigation was primarily concerned with (1) the development of cavitation free entrance shapes, (2) the determination of the hydraulic thrust on the emergency gate for different openings and discharge conditions, (3) the observation of mechanical vibrations on the gates, and (4) the performance of the energy dissipator.
- (f) Completed.
- (h) "Pillur Dam Scour Vent Hydraulic Model Tests", by Andre Galarneau and Raymond Boucher, April 1964, submitted to sponsor.
- (5513) HYDRAULIC MODEL STUDY OF THE INTAKE FOR THE MANICOUAGAN 5 HYDRO-ELECTRIC PROJECT.
- (b) Quebec Hydro-Electric Commission.
- (c) Professor Raymond Boucher, Director, Hydrodynamics Laboratory, Ecole Polytechnique, 2500 Marie-Guyard Ave., Montreal 26, Quebec, Canada.
- (d) Experimental; for design.
- (e) A comprehensive model built to an undistorted scale of 1:60 reproduces the forebay and intake structures. This investigation is conducted to examine the overall performance of the structures and to verify the design.

UNIVERSITY OF GUELPH, Department of Engineering Science.

- (2492) RUNOFF FROM SMALL WATERSHEDS.
- (b) Laboratory project.
- (c) Prof. H. D. Ayers, Univ. of Guelph, Guelph, Ontario, Canada.

- (d) Experimental; applied research.
 - (e) The relationship of precipitation and snow-melt to runoff characteristics on four watersheds of 20 acres each, under various land use practices, is being evaluated.
 - (g) Winter surface runoff from watersheds with good grass-legume cover is greater than from watersheds plowed during the winter season. Negligible surface runoff from watershed in trees and pasture.
 - (h) "Effects of Agricultural Land Management on Winter Runoff in the Guelph, Ontario Region," H. D. Ayers. Proceedings of Hydrology Symposium No. 4, National Research Council, Associate Committee on Geodesy and Geophysics, Sub-committee on Hydrology, 1964.
- "Runoff From Rainfall on Small Rural Watersheds," D. F. Witherspoon, Transactions Engineering Institute of Canada, 6: A-10, 1963.
- (2740) MAIN TILE DRAIN SIZES FOR COMPOSITE DRAINAGE OF BROOKSTON CLAY SOIL.
- (b) Laboratory project.
 - (c) Prof. F. R. Hore, Univ. of Guelph, Guelph, Ontario, Canada.
 - (d) Field investigation; applied research.
 - (e) Discharge measurements from lateral tile drains in Brookston clay soil are being made to determine the proper drainage coefficient to use in the design of main tile drains and to determine the effect of lateral tile drain spacing on the drainage rate.
 - (g) Preliminary frequency analyses have been made on runoff data collected over a 5-year period.
- (3363) HYDROLOGIC CHARACTERISTICS OF ORGANIC SOIL.
- (b) Laboratory project.
 - (c) Prof. R. W. Irwin, Univ. of Guelph, Guelph, Ontario, Canada.
 - (d) Field investigation; applied research.
 - (e) The study is being carried out to establish criteria to be used in the development and operation of a water control project for organic soils. In the investigation, an attempt will be made to establish a hydrologic water balance for the field area by measuring, recording, and analyzing so far as possible the evaporation, seepage, transpiration, precipitation, water table elevation and ground water discharge through tile drains.
 - (g) Data collection is continuing. The physical properties of the organic soil have been determined and the results are presently being analyzed.
 - (h) "Determination of Subsidence of an Organic Soil in Southern Ontario," C. Mirza and R. W. Irwin, Canadian Journal of Soil Science, 44: 248-253, 1964.
- (3658) THE RESISTIVITY METHOD OF GROUND WATER PROSPECTING.
- (b) Laboratory project.
 - (c) Prof. F. R. Hore, Dept. of Engineering Science, Univ. of Guelph, Guelph, Ontario, Canada.
 - (d) Field investigation; applied research.
 - (e) The objective is to investigate the application of the resistivity method to subsurface exploration for ground water under the geological conditions found in southern Ontario.
 - (f) Completed.
 - (g) The Schlumberger configuration was found to be a rapid and satisfactory method for prospecting. Depth-to-bedrock interpretation was found to be feasible using the Enslin method. Interpretation of two, three and four layer cases was possible when the layers were of sufficient thickness and had the necessary resistivity contrast. Interpretations of depth to water table were possible in the sand plains area where the unsaturated layer was free of clay. A report on the study in the Big Creek Region of Ontario is under preparation.
- (3660) RAINFALL-DEPTH-AREA-INTENSITY RELATIONSHIPS IN CENTRAL ONTARIO.
- (b) Laboratory project.
 - (c) Prof. H. D. Ayers, Univ. of Guelph, Guelph, Ontario, Canada.
 - (d) Field investigation; applied research.
 - (e) A dense network of standard and recording rain gages has been established in the Guelph area with the cooperation of the Meteorological Branch, Department of Transport. The network is over an area of approximately 12 square miles with an average gage density of 1 per square mile. The purpose of this study is to obtain detailed information on summer precipitation characteristics for use in the hydrologic design for small drainage basins.
 - (f) Completed.
 - (g) Analysis of data shows that for 8 years intensity-frequency relationships are different from nearby stations with longer record.
 - (h) "A Severe Thunderstorm at Guelph, Ontario, June 23, 1964," W. T. Dickinson, No. 11, Dept. of Engineering Science, Univ. of Guelph, 1964.
- "A Comparative Study of Rain Gauges at Guelph, Canada," W. T. Dickinson, Proceedings of Hydrology Symposium No. 4, National Research Council Associate Committee on Geodesy and Geophysics, Sub-committee on Hydrology, 1964.
- (3662) POTENTIAL EVAPOTRANSPIRATION AND CONSUMPTIVE USE OF WATER BY CROPS.
- (b) Laboratory project.
 - (c) Dr. K. M. King, Department of Engineering Science, Univ. of Guelph, Guelph, Ontario, Canada.
 - (d) Field investigations; basic research.
 - (e) The purpose of this investigation is to evaluate the factors influencing evapotranspiration by the use of a specially designed floating lysimeter. Study is being conducted on the effect of soil moisture on the heat budget and evapotranspiration for crops.
 - (g) Errors due to temperature variations in zinc chloride filled floating lysimeters were found to be much more serious than those in water filled floating lysimeters.
- (4052) COVER MATERIALS FOR TILE DRAINS.
- (b) Laboratory project.
 - (c) Prof. F. R. Hore, Univ. of Guelph, Guelph, Ontario, Canada.
 - (d) Experimental and field investigation; applied research.
 - (e) This study is being made to determine the effect of several cover materials on soil movement and water discharged into a tile drain. Laboratory studies of some relatively new glass fiber materials have been completed and a field experiment based on those results was installed in the fall of 1960.
 - (g) Biennial sampling of sediment from drains at the field experimental site is being continued.
- (4054) RUNOFF FROM FLAT LAND.
- (b) Laboratory project in cooperation with Water Resources Division, Department of Northern Affairs and National Resources.
 - (c) Prof. F. R. Hore, Univ. of Guelph, Guelph, Ontario, Canada.
 - (d) Field investigation; applied research.
 - (e) Four 2 to 10 square mile flat watersheds of fine-textured soils are to be studied to determine the relationship between precipitation, snowmelt, watershed characteristics and runoff. These watersheds are distributed geographically over Southern Ontario. Hydrologic data on this type of watershed are being sought for the establishment of criteria for the design of drainage structures.
- (4925) MECHANICAL DRAINAGE OF AGRICULTURAL LANDS.
- (b) Laboratory project.
 - (c) Prof. R. W. Irwin, Univ. of Guelph, Guelph, Ontario, Canada.

- (d) Field investigation; applied research.
 (e) Discharge measurements and stage measurements from three pump drainage sites are being recorded together with precipitation values.
 (g) Data collection is continuing.
- (5508) TRANSIENT PRESSURE AND WATER CONTENT DISTRIBUTIONS IN SOIL - WATER FLOW SYSTEMS.
- (b) Laboratory project.
 (c) Prof. W. N. Stammers, Dept. of Engineering Science, Univ. of Guelph, Guelph, Ontario, Canada.
 (d) Experimental, theoretical; applied research.
 (e) Experimental and analytical investigation of transient soil water flow systems with saturated and unsaturated flow regions is being investigated.
- (5509) MOISTURE BALANCE AND IRRIGATION REQUIREMENTS.
- (b) Laboratory project.
 (c) Prof. H. D. Ayers, Dept. of Engineering Science, Univ. of Guelph, Guelph, Ontario, Canada.
 (d) Experimental, applied research.
 (e) A daily moisture budget based on four different soil moisture storage models is being computed for a ten year period at ten sites in Southern Ontario. The budgeting procedure is based on actual precipitation data and evapotranspiration determined from meteorological conditions and an empirical moisture depletion model. A synthetic irrigation schedule is superimposed upon the moisture budget in a supplementary computer program.
 (g) The average annual irrigation requirement for perennial vegetation varied from approximately 9 inches for coarse textured soils of low moisture storage capacity to about four inches for soils of high storage capacity.
- (5510) GEOLOGICAL INFLUENCES ON STREAM FLOW.
- (b) Laboratory project.
 (c) Prof. H. D. Ayers, Dept. of Engineering Science, Univ. of Guelph, Guelph, Ontario, Canada.
 (d) Experimental, applied research for Master of Science Degree.
 (e) Various stream flow parameters such as flow duration curve, groundwater recession constant, uniformity of monthly discharge and other indices are being compared on drainage basins of differing surficial geology in Southern Ontario. The geological conditions range from fine-textured soils formed on till to coarse textured soils formed on sands and gravel.
- (5511) UNIT HYDROGRAPHS FOR ONTARIO WATERSHEDS.
- (b) Laboratory project.
 (c) Prof. H. D. Ayers, Dept. of Engineering Science, Univ. of Guelph, Guelph, Ontario, Canada.
 (d) Experimental, applied research for Master of Science Thesis.
 (e) Unit hydrographs were developed for five watersheds in the region. Methods of base flow separation were compared. Effects of areal and time distribution and magnitude of rainfall on unit hydrograph were assessed.
 (f) Completed.
 (g) There was no significant effect on the unit hydrograph peak which could be attributed to the areal or time distribution of rainfall or the actual amount of rainfall involved in the storm runoff hydrograph.
 (h) "Unit Hydrograph Characteristics of Selected Ontario Watersheds," W. T. Dickinson, M.S.A. Thesis, Ontario Agricultural College, Univ. of Toronto, 1963.
- (5512) BASIN PHYSIOGRAPHY AND HYDROGRAPH CHARACTERISTICS.
- (b) Laboratory project.
 (c) Prof. H. D. Ayers, Dept. of Engineering Science, Univ. of Guelph, Guelph, Ontario, Canada.
- (d) Experimental, applied research for Master of Science Thesis.
 (e) Hydrographs and physiographic parameters of eleven watersheds in Southern Ontario were determined. The time of concentration was determined for each hydrograph.
 (f) Completed.
 (g) A multiple regression equation for time of concentration as a function of physiographic characteristics was developed. This relationship was compared with other empirical formula for time of concentration.
 (h) "The Time of Concentration For Selected Rivers From Watershed Characteristics," P. N. Gryniowski, M.S.A. Thesis, Ontario Agricultural College, Univ. of Toronto, 1964.
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- THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO, Hydraulic Model Laboratory.
- Inquiries concerning the following projects should be addressed to Mr. J. B. Bryce, Hydraulic Engineer, Hydraulic Generation Department, 620 University Avenue, Toronto 2, Ontario, Canada.
- (4026) NIAGARA RIVER MODEL.
- (b) Ontario Hydro.
 (d) Experimental; for design and operation.
 (e) An existing 1:250 x 1:50 scale model reproducing five miles of the Niagara River from Buckhorn Island to below the Cataracts is being used to determine the operational characteristics of the Niagara River Control Structure under developed conditions. This model was previously used to investigate the remedial works necessary for the Preservation and Enhancement of Niagara Falls and for the location of the intakes and necessary river improvements of both Ontario Hydro and the Power Authority of the State of New York. To fully realize the terms of the 1950 Niagara Treaty, additional remedial works have been designed. These include a five-gate extension to the existing 13-gate control structure as well as a system containing an upstream accelerating wall, a downstream training wall and overflow weir for the safe passage of ice past the various intakes along the Canadian shore of the river above the Falls. The sequence of construction of these works and the conditions during their construction were determined in the model. Rating of the structure under cofferdammed conditions was obtained. An echo-sounding survey with electronic fixing was made in the field in 1962 and portions of the model re-contoured. Certain river improvements were designed and executed to assist in the passage of ice floes.
- (4455) ARROW LAKES DAM - COLUMBIA RIVER.
- (b) British Columbia Hydro and Power Authority.
 (d) Experimental; for design and operation.
 (e) An 1:80 scale model of the Arrow Lakes and dam and environs was built to determine the detailed location and adequacy of the water passages in a concrete structure and the energy-dissipating works necessary to ensure the protection of an associated earth dam. Numerous tests have been made with a movable bed of fine sand to determine erosion characteristics and navigation velocities upstream and downstream of a lock situated between the concrete structure and the earth dam.
 A 1:50 scale model was tested in a flume to determine the hydraulic design of the tunnel ports in the concrete structure and to develop the associated energy-dissipating work. Rating of these ports was obtained as well as the hydraulic loadings on the port gates. A 1:60 scale model of one of the four sluiceways is being tested in the flume to determine

the rating of the sluice and the hydraulic loadings on the sluice gate. Piezometers are being used to determine under varying conditions of flow, the rollway pressures as well as the pressures at selected locations in the energy-dissipating bucket and associated tooth-like projections of the dissipator.

model will determine the location and size of the intake channels for cooling water and any river excavation for the channel and shipping.

(f) Model under construction.

(4963) KIPLING GENERATING STATION MODEL.

- (b) Ontario Hydro.
- (d) Experimental; for design.
- (e) A 1:80 scale comprehensive model has been constructed of the main dam containing two submerged tunnel ports and two sluiceways to determine the dewatering arrangement for construction, cofferdam location and elevations, velocities during closure of cofferdam and the rating of the diversion ports during construction of main dam and sluiceways.
- The elevations and lengths of training walls, and the length of a concrete apron downstream of the sluices were determined by experiment.
- (f) Work is complete and model inactive.

(4964) LAKEVIEW THERMAL GENERATING STATION - RECIRCULATION STUDY OF CONDENSER COOLING WATER.

- (b) Ontario Hydro.
- (d) Experimental; for design and operation.
- (e) A 1:24 natural scale model was constructed of the intake channel from Lake Ontario and pump wells for the condenser cooling water of the eight 300-megawatt thermal units. By design of the alignment of the excavated rock canal walls and the introduction of warm condenser water through a "y" branch pipe into the canal, efficient distribution of the warm water across the pump wells was achieved under a variety of pumping conditions in order to prevent ice difficulties at the travelling screens.
- (f) Work is completed and model removed.

(5514) KIPLING GENERATING STATION - TAILRACE MODEL.

- (b) Ontario Hydro.
- (d) Experimental; for design.
- (e) A 1:50 scale model of the draft tubes of the four turbines and tailrace was constructed to study whether a 3 to 1 slope up from the units was possible rather than a 4 to 1 slope due to the confining nature of the downstream topography.
- (f) Work completed and model removed.

(5515) LAKEVIEW GENERATING STATION - UNITS 7 and 8.

- (b) Ontario Hydro.
- (d) Experimental; for design and operation.
- (e) A 1:16 plastic scale model was built of the 7-foot diameter condenser cooling water pipes and the branch 5-foot diameter pipes, expanders and various degree elbows leading to and from the condenser box. By experiment the actual division of pipe flow to and from the condenser was found as well as the vanes necessary to provide equal flow in the branch pipes.
- (f) Work completed and model inactive.

(5516) SIR ADAM BECK-NIAGARA GENERATING STATIONS.

- (b) Ontario Hydro.
- (d) Experimental; for design.
- (e) A 1:80 scale model was built of the two canals leading to the plants including the crossover, in order to determine the performance with the increased flow of Sir Adam Beck No. 1 canal due to its enlargement.

(5517) LAMBTON GENERATING STATION.

- (b) Ontario Hydro.
- (d) Experimental; for design.
- (e) A 1 to 80 scale model reproduces about one mile of the St. Clair River topography. The

LASALLE HYDRAULIC LABORATORY LTD.

(4456) VELOCITY AND DIRECTION OF CURRENT RECORDER.

- (b) Laboratory Project.
- (d) Experimental - development of instrument for hydrographic and oceanographic research for acquisition of datum in computable form (punched tape).
- (e) Recording of velocity by impulse counter for propeller type current-meter. Recording of direction by reading an encoder monitored by a marine compass. Instrument must be: 1) rugged, 2) simple and easy to maintain, 3) very low power drain for long periods. (recording up to 6 months under ice).
- (f) Prototype studies and tests completed.
- (g) Industrial instrument design and industrial prototype completed. Ready for marketing.

(4517) MONTREAL - SOREL SHIP CHANNEL.

- (b) Department of Transport.
- (d) Theoretical and experimental; design.
- (e) Two models representing a section of the St. Lawrence River from Laprairie Basin including Montreal Harbour to Sorel Islands were built at a scale 1/150 vertically and 1/600 horizontally.
- The purpose of the model was to study the improvement of navigation in this section of the St. Lawrence River.

(4965) ST. TIMOTHEE REACH.

- (b) Hydro - Quebec, and consulting engineers.
- (d) Experimental; design.
- (e) Study on an undistorted 1/100 scale model of three different solutions to the water level control problem in the St - Timothee reach, including studies of coffer damming, spillways, dikes along the reservoir, currents.
- (f) Completed.
- (g) Report submitted to sponsor.

(5414) PROMENADE DRIVE ALONG RIVIERE DES PRAIRIES.

- (b) Dept. of Public Works, City of Montreal.
- (d) Theoretical; design.
- (e) Part I. Influence of the projected road embankment upon back water and ice cover profiles along the encroached reach of the river.
- Part II. Protection of embankment against current and wave action.
- (f) Completed.
- (g) Report submitted to sponsor.

(5415) DRAINAGE OF VERSANT SUD SEWER COLLECTOR ST. JACQUES YOVILLE.

- (b) Dept. of Public Works, City of Montreal.
- (d) Theoretical; design.
- (e) Hydrology and circular sewer collector design in combined system including high water flow interception device and storm water flow meter.
- (f) Completed.
- (g) Report submitted to sponsor.

(5416) ROAD TUNNEL LAPONTAINE (MONTREAL BOUCHERVILLE).

- (b) Atlas Wilson and Janin, contractors (joint venture).
- (d) Experimental; design.
- (e) Study of the hydrodynamic forces horizontal and vertical, acting on a concrete element of tunnel and accompanying barges during the warping and sinking operations.
- Tests are carried out in a flume 30' long x 11' wide reproducing a part of the river,

the excavated trench, a calibrated plexi-glass model of tunnel element and sunken element in final position (scale 1/84).

(5417) EROSION STUDY OF CLAY SAMPLES.

- (b) Dept. of Transport of Canada, Marine Works Branch.
- (d) Theoretical and experimental; basic research.
- (e) Two series of tests are conducted with undisturbed clay soil samples, and another series is carried out with the clay in the comparatively remoulded state. Results of hydraulic testing, fundamental differences between behaviour of cohesive and non-cohesive materials, and difficulties of scaling-up such flume results are dealt with in the report.
- (f) Completed.
- (g) Report submitted to sponsor.

(5418) MATANE HARBOUR.

- (b) Dept. of Public Works of Canada (Harbours and Rivers Engineering Branch), and consulting engineers.
- (d) Experimental; applied research, design.
- (e) Wave forecast study - an undistorted 1/100 scale model is used to measure wave action within the harbour and to determine the optimum harbour layout. Stability studies will follow.

(5419) RIVIERE DES PRAIRIES - MARINA.

- (b) Dept. of Public Works, City of Montreal.
- (d) Theoretical; design.
- (e) Planning of a small-craft harbour, including layout planning, wave action, berthing facilities and services.
- (f) Completed.
- (g) Report submitted to sponsor.

(5420) 1967 WORLD EXHIBITION MARINA.

- (b) Canadian Corporation for the 1967 World exhibition, and consulting engineers.
- (d) Experimental and theoretical; design.
- (e) Various points are investigated: reduction of currents in the entrance by means of a deflector; wave action within the marina; wind effects in relation to safe entry and exit.
- (f) Completed.
- (g) Report submitted to sponsor.

(5421) CLOSURE OF DIVERSION TUNNELS - MANICOUAGAN V.

- (b) Hydro - Quebec.
- (d) Theoretical; design.
- (e) Down-pull calculation with existing gates, or with grids to be obturated in place; - air vent calculations downstream from the gates.
- (f) Completed.
- (g) Report submitted to sponsor.

(5422) SINKING OF CAISSON FOR THE WORLD'S FAIR BRIDGE.

- (b) Dufresne Engineering Corporation Limited.
- (d) Experimental; design.
- (e) Scale model to study sinking of large caissons in 15 ft/sec. current. Determination of hydrodynamic forces for optimum anchor systems.
- (f) Completed.
- (g) Report submitted to sponsor.

(5423) CONSTRUCTION OF A DYKE BY THE METHOD OF TOE-DUMPING.

- (b) Canadian Corporation for the 1967 World Exhibition, and consulting engineers.
- (d) Theoretical and experimental; design.
- (e) A dyke is to be built to cut an arm of the St. Lawrence river between St. Helen's Island and Notre Dame Island in Montreal harbour. The theoretical and experimental studies were to determine the evolution of

discharges, water levels and rock fill sizes necessary as the dyke progresses across the arm through the toe-dumping method.

- (f) Completed.
- (g) Report submitted to sponsor.

(5424) ICE CONTROL STRUCTURE IN LAPRAIRIE BASIN.

- (b) Dept. of Public Works, Canada; and consulting engineers.
- (d) Theoretical and experimental; design.
- (e) Scale model of ice cover deformation and evolution under hydrodynamic forces and erosive action as influenced by the construction of an ice control structure upstream from Montreal harbour.
- (f) Completed.
- (g) Report submitted to sponsor.

(5425) LITTLE CURRENT SHIP PASSAGE.

- (b) Dept. of Public Works, Canada, and consulting engineers.
- (d) Scale model study of navigation problems in Little Current Narrows. Study of corrective measures for currents induced by wind, tide and seiche action.

(5426) OUTARDES RIVER DIVERSION WORKS.

- (b) Hydro - Quebec and consulting engineers.
- (d) Experimental; design.
- (e) A 1/96 scale model of single 49.5' diameter unlined diversion tunnel. Study of general performance, erosion, flow stability in conduit, etc. Study of the construction of the cofferdam by the toe-dumping method.

(5427) ARROW LAKES LOCK.

- (b) C B A Engineering Ltd.
- (d) Experimental; design.
- (e) The purpose of the study carried out on a 1/20 scale model is to ascertain the hydraulic performance of the design of the lock and make the modifications suggested by these preliminary tests.

(5428) PEACE RIVER TAILRACE.

- (b) I P E C (International Power and Engineering Consultants Ltd).
- (d) Experimental and theoretical; design.
- (e) Study on a 1/96 scale model of the head losses and surge waves in the tailrace manifold and tunnel. A special study of the surge waves in the tailrace tunnel is also carried out on a computer.

(5429) SNOW MELTING DEVICE.

- (b) City of Montreal.
- (d) Theoretical and experimental; design.
- (e) Study of the hydraulic problems pertaining to snow melters in order to improve their operation.

(5430) BACK FILLING IN THE ST. LAWRENCE RIVER.

- (b) City of Montreal.
- (d) Experimental study.
- (e) Model study to determine the effect on water levels and ice conditions of a multi-acre back filled area at Point - St - Charles in the St. Lawrence River.
- (f) Completed.
- (g) Report submitted to sponsor.

(5431) LOG PASSAGE IN A DIVERSION TUNNEL.

- (b) Hydro - Quebec and consulting engineers.
- (d) Theoretical study.
- (e) Theoretical study of the different phases of log passage in a diversion tunnel: (1) Floating of logs; (2) formation of a sliding cover; (3) characteristics of an immobile cover; (4) evolution of the thickness of the cover under erosion or deposition; (5) characteristics of stabilized cover; and

- (6) transportation capacity of tunnel with stable log cover.
 (f) Completed.
 (g) Report submitted to sponsor.
- (5432) GREEN ST. EMILIE SEWER.
 (b) City of Montreal.
 (d) Theoretical; design.
 (e) Study and design of a special automatic flushing device for a long low sloped sewer. The study also includes the design of a 70' high sewer drop.
 (f) Completed.
 (g) Report submitted to sponsor.
- (5433) DRAINAGE OF THE RIVIERE DES PRAIRIES DISTRICT.
 (b) City of Montreal.
 (d) Theoretical; design.
 (e) Hydraulic design of a 6 mile long combined sewer, draining an 8000 acre basin along the Riviere des Prairies. The sewer includes along its course three storm overflows, but as the sewer has been designed to store a large volume of storm water, the overflows will discharge in the river not more than three times a year, each discharge being of short duration and the quantity of B.O.D. released during this time will be comparable to that of a water sewage treatment plant effluent.
 (f) Completed.
 (g) Report submitted to sponsor.
- (5434) MAISONNEUVE SEWER.
 (b) City of Montreal.
 (d) Theoretical; design.
 (e) Study and design of a special automatic flushing device to prevent sedimentation in a locally submerged sewer. The proposed device stores the dry water flow in the sewer itself, and quickly releases the water by means of a siphon. The design includes any movable mechanical part.

MCGILL UNIVERSITY, Department of Civil Engineering and Applied Mechanics.

- (4545) BREAKUP OF SOLITARY WAVE.
 (b) Laboratory project.
 (c) Dr. A. J. Reynolds, Dept. of Civil Engineering and Applied Mechanics, McGill University, Montreal 2, P.Q., Canada.
 (d) Experimental; basic research.
 (e) Examination of disintegration of a solitary wave in shallow water on encountering deep water.
 (f) Completed.
- (4546) CAVITATION AT HIGH-HEAD SLUICE GATES.
 (b) National Research Council, Canada.
 (c) Dr. A. J. Reynolds, Dept. of Civil Engrg. and Applied Mechanics, McGill Univ., Montreal 2, P. Q., Canada.
 (d) Experimental; applied research, for Doctoral degree.
 (e) Study of pressure fluctuations on wall behind an obstruction which produces cavitation.
 (f) Work transferred to 11" by 11" water tunnel.
 (g) The flow was established in a syphon tunnel of section 3" by 3". Mean pressure distributions were measured for a wide range of blockage ratios, with and without air addition. Overall pressure recovery was found to be accurately predicted by momentum balance assuming one-dimensional flow. Length of eddy behind gate (without air addition) agreed with previous measurements of Rouse and Fortmann. The length of the eddy was found to be as much as twice that of the eddy formed in the very similar flow

at a sluice gate beyond which there is a nearly level free surface.

- (4923) DIVISION OF OPEN-CHANNEL FLOW.
 (b) National Research Council, Canada.
 (c) Dr. A. J. Reynolds, Dept. of Civil Engineering and Applied Mechanics, McGill Univ., Montreal 2, P.Q., Canada.
 (d) Experimental; basic research, for Master's degree.
 (e) Detailed examination of flow at junction between straight channel and a branch at 90°.
 (f) Detailed study of flow at junction under way.
 (g) All three sections of the experimental channel are 8" wide, the walls and bottom being plexiglas and painted steel. The features noted in several earlier studies of such flows have been fitted into a consistent pattern. Simple mathematical models have been found to describe almost every feature of the flow well away from the junction.
- (4924) WAVES IN AND NEAR PACK ICE.
 (b) Defence Research Board, Canada.
 (c) Dr. A. J. Reynolds, Dept. of Civil Engineering and Applied Mechanics, McGill Univ., Montreal 2, P.Q., Canada.
 (d) Theoretical and experimental; basic and applied research, for Master's degree.
 (e) Study of fundamental mechanical processes of interaction between surface waves and floating elastic bodies.
 (g) Experiments under way.
- (5280) UNIFORM DISTORTION OF TURBULENCE.
 (b) Defence Research Board, Canada.
 (c) Dr. A. J. Reynolds, Dept. of Civil Engrg. and Applied Mechanics, McGill Univ., Montreal 2, P.Q., Canada.
 (d) Experimental; basic research for Doctoral thesis.
 (e) Study of uniformly distorted turbulence to investigate the approach to equilibrium structure and the nature of that structure.
 (g) Special wind tunnel under construction.

NATIONAL RESEARCH COUNCIL, Division of Mechanical Engineering.

Inquiries concerning the following projects should be addressed to Dr. D. C. MacPhail, Director, Division of Mechanical Engineering, National Research Council, Montreal Road, Ottawa, Ontario, Canada.

- (4047) BAIE COMEAU, PROVINCE OF QUEBEC.
 (b) Department of Public Works, Canada.
 (d) Experimental; for design.
 (e) The new development of the harbour is completed. It involves a perforated vertical-wall breakwater, 1000 ft. long, 60 ft. wide, 56 ft. high, built as the extension to an existing wharf.
 (g) Observations have shown the breakwater to perform in a satisfactory manner during storms. The wave run-up appears to be suppressed and no erosion can be observed at the toe. The breakwater can thus provide berthing facilities as well as harbour protection.
- (4464) RUSTICO HARBOUR, PRINCE EDWARD ISLAND.
 (b) Department of Public Works, Canada.
 (d) Experimental for design.
 (e) A 1:150 by 1:30 wave and tidal model with movable bed of crushed bakelite was made to study harbour inlet instability and to determine suitable remedial measures.
 (f) Model study completed and recommendations issued to sponsor.
 (g) Shallow water interaction between waves and currents found to be responsible for

- (h) instability rather than littoral drift.
"Basic Experiments on the Development of Coastal Inlets With and Without Wave Action," K. L. Philpott, Proc. Xth I.A.H.R. Congress, pp. 303-310, London, September 1963.
- (4466) AIR BUBBLERS.
- (b) Laboratory project.
 - (d) Experimental; field investigations.
 - (e) Field measurements and laboratory tests were performed to determine the mechanism whereby an air bubbler prevents ice formation in an oceanic environment.
 - (g) Field measurements afforded a clear picture of the mechanism and heat balance of the air bubbler operation. In most oceanic environments the air bubbler will be effective with varying degrees of efficiency.
- (4525) FORMATION OF ICE IN RIVERS.
- (b) Laboratory project.
 - (d) Experimental; field investigations.
 - (e) Water temperatures are being recorded in the St. Lawrence River between Kingston, Ontario, and Three Rivers, Quebec, to obtain information on heat losses.
 - (g) Preliminary calculations show satisfactory agreement between measured and computed heat losses. For closer correlation more precise measurement of meteorological conditions- particularly radiation- will be necessary.
- (4527) TIDE PROPAGATION IN AN ESTUARY.
- (b) Laboratory project.
 - (d) Theoretical and experimental.
 - (e) During the last 25 years, several structures have been built in the estuary of the Fraser River, B.C., to increase locally the depth of the navigation channel. A 1:1440 by 1:144 fixed-bed model of the entire tidal section has been constructed to determine the actual effect of such structures on the tidal propagation.
 - (g) The model has been calibrated for different discharge conditions and the first series of tests was started during September 1963.
- (4528) EFFECT OF EARTH'S ROTATION ON RIVER FLOW.
- (b) Laboratory project.
 - (d) Theoretical and experimental.
 - (e) Considerations of gravity and Coriolis forces acting in fast-flowing, straight rivers of small slope indicate that considerable spiral flow is possible. A small rotating table has been constructed to study flow in channels in a rotating system.
- (5090) CODROY HARBOUR, NEWFOUNDLAND.
- (b) Department of Public Works, Canada.
 - (d) Experimental, for design.
 - (e) A 1:180 by 1:120 fixed-bed wave and current model of the harbour has been constructed to investigate silting conditions in the harbour entrance and to devise remedial works.
- (5091) ST. BRIDES HARBOUR BREAKWATER, NEWFOUNDLAND.
- (b) Department of Public Works, Canada.
 - (d) Experimental for design.
 - (e) A 1/36 scale model of a proposed partially submerged breakwater was tested in a wave flume to determine its effectiveness in providing protection seaward of an existing structure.
 - (f) Completed, results reported to sponsor.
- (5092) BRANCH HARBOUR, NEWFOUNDLAND.
- (b) Department of Public Works, Canada.
 - (d) Theoretical for design.
 - (e) A study of methods of reducing or eliminating the need for regular maintenance dredging, by making use of a river for flushing combined with reduction of littoral drift
- passing the harbour entrance.
- (5093) GENERAL HARBOUR STUDIES.
- (b) Laboratory project, sponsored in part by Dept. of Public Works, Canada.
 - (d) Field and theoretical, applied research.
 - (e) A general study of the hydraulic aspects of harbour design with the eventual objective of standardizing procedures and, if possible, designs, for relatively simple situations not requiring model studies. The first stage concerns evaluation of design conditions and in this connection a method of processing wind data for estimation of wave probabilities is under study.
- (5094) PERFORATED VERTICAL-WALL BREAKWATER.
- (b) Laboratory project.
 - (d) Experimental and theoretical.
 - (e) Two-dimensional flume experiments are being made to determine the behaviour of an erodible bed in front of the breakwater.
 - (g) Results obtained hitherto indicate that, for a non-cohesive bed, no erosion develops at the toe of the breakwater regardless of the wave height or period.
 - (h) A report will be prepared.
- (5095) DINGWALL HARBOUR, NOVA SCOTIA.
- (b) Department of Public Works, Canada.
 - (d) Experimental.
 - (e) Model study of a harbour subject to heavy sedimentation (sand) induced by waves.
 - (f) The model study has been completed, but the study is still active.
 - (g) The harbour entrance has been rebuilt. It involves four rubble-mound breakwaters forming a wave energy trap. Results indicate that no shoaling of the entrance occurs.
 - (h) Report is in preparation.
- (5096) SAULNIERVILLE HARBOUR, NOVA SCOTIA.
- (b) Department of Public Works, Canada.
 - (d) Theoretical and field investigation.
 - (e) Development of a new harbour involving a perforated vertical-wall breakwater.
-
- QUEEN'S UNIVERSITY AT KINGSTON, Hydraulic Laboratories.
- (3364) LITTORAL DRIFT AND ITS EFFECT ON THE HARBOURS ON THE NORTH SHORE OF LAKE ONTARIO.
- (b) The National Research Council of Canada.
 - (c) Dr. A. Brebner, Ellis Hall, Queen's Univ., Kingston, Ontario, Canada.
 - (d) Experimental and field; basic and applied.
 - (e) Two dimensional investigation of mass transport and sediment movement with and without superimposed currents; three-dimensional model investigation of the waves generated by a moving vessel in shallow water; two-dimensional investigation of the use of floating breakwaters of logs as wave energy dissipators.
 - (h) "Model Tests on the Relationship between Deep water Wave Characteristics and Longshore Currents", A. Brebner and J. W. Kamphuis. Proc. 9th Conf. on Coastal Engineering, Lisbon 1964.
"Determination of Design Waves for the Great Lakes", A. Brebner. Proc. 7th Conf. on Great Lakes Research, Toronto, 1964.
"A Comparison of Actual with Predicted Wave-Heights and Periods for the North Shore of Lakes Ontario and Erie", A. Brebner. J. Eng. Inst. of Canada, March 1964.
- (4057) THE TRANSPORT OF MATERIAL IN PIPE-LINES.
- (b) The National Research Council of Canada.
 - (c) Dr. A. Brebner, Ellis Hall, Queen's Univ., Kingston, Ont., Canada.

- (d) Laboratory investigation.
 - (e) Pipes of differing shapes being used to study the parameters affecting the critical velocity of deposition.
 - (h) "On the Pumping of Wood-Chips Through a Four-inch Aluminum Pipe-Line", A. Brebner. Canadian Journal of Chemical Engineering, June 1964.
- "On the Hydraulic Efficiency of Aluminum Pipe over a Large Range of Reynolds' Numbers", A. Brebner. Canadian Journal of Chemical Engineering, Feb. 1964.
- (4468) CRITERIA FOR THE INCIDENCE OF TURBULENCE.
- (b) National Research Council.
 - (c) Prof. R. J. Kennedy, Queen's Univ., Kingston, Ont., Canada.
 - (d) Basic research for Master's Degree.
 - (e) Plane couette flow examined by electrolysis and movie camera.
- (4530) THE VERTICAL PUMPING OF MINE PRODUCTS.
- (b) Ontario Mining Association.
 - (c) Dr. A. Brebner, Ellis Hall, Queen's Univ., Kingston, Ontario, Canada.
 - (d) Applied research.
 - (e) The establishment of co-relations between head losses, concentration, etc.
 - (h) "The Hydraulic Hoisting of a Magnetite Slurry", A. Brebner and P. Kostuik. Queen's C.E. Report No. 38, June 1964.
- (5287) LABORATORY INVESTIGATION OF THE INTENSITIES OF SECONDARY CURRENTS IN AIR FLOWS.
- (b) National Research Council of Canada.
 - (c) Prof. S. S. Lazier, Queen's Univ., Kingston, Ontario, Canada.
 - (d) Basic research for Master's Degree.
 - (g) Report being prepared.
- (5288) ON EFFICIENT MEANS OF PASSING PULPWOOD OVER A WEIR IN HYDRO-ELECTRIC INSTALLATIONS.
- (b) Pulp and Paper Research Institute of Canada.
 - (c) Prof. R. J. Kennedy, Queen's Univ., Kingston, Ontario, Canada.
 - (d) Applied research.
 - (f) Work completed and report submitted to sponsor.
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- UNIVERSITY OF TORONTO, Department of Mechanical Engineering.
- (1298) DISCHARGE CHARACTERISTICS OF WEIR-TYPE SPILLWAYS.
- (b) Laboratory project.
 - (c) Prof. L. E. Jones, University of Toronto, Toronto 5, Canada.
 - (d) Experimental; applied research for master's theses.
 - (e) A long-term research carried out with a view to systematizing discharge characteristics for spillways having various pier spacings and proportions.
 - (g) Significant correlations obtained via special plotting techniques.
 - (h) Report in preparation.
- (3003) ROUGHNESS PHENOMENA IN OPEN CHANNEL FLOW.
- (b) Laboratory project.
 - (c) Prof. L. E. Jones, University of Toronto, Toronto 5, Canada.
 - (d) Experimental and analytical; basic research for doctoral thesis.
 - (e) Critical analysis of the hydraulic radius concept and the effect of cross-section geometry on the resistance to flow in conduits. Detailed evaluation of mean flow parameters such as friction coefficients, static pressures, velocities, and wall shear stresses. The channel under study was 70 feet long and had a variable rectangular cross-section of 3 x 1, 3, 9 inches, respectively, and used air as the fluid medium. First project completed; others in progress.
- (3368) DIFFUSION OF GASEOUS PLUMES.
- (b) Laboratory project.
 - (c) Prof. W. D. Baines, University of Toronto, Toronto 5, Canada.
 - (d) Experimental and analytical; basic research for Master's thesis.
 - (e) A jet of air at ambient or higher temperature is injected at various angles into a uniform cross-flow. From photographs of the jet containing smoke, and velocities determined with a hot-wire anemometer, the shape of the jet and the pattern of dispersion are being studied.
 - (g) Momentum equations yield parametric relationships for the shape of the jet which have been used to define the path of a jet injected at 90 degrees to the cross-flow. Experiments are in progress with jets entering at other angles.
 - (h) "Profiles of the Round Turbulent Jet in a Cross-Wind", by B. D. Pratte, M.A.Sc. thesis, Univ. of Toronto, 1964.
- (4469) DIFFUSION OF MOMENTUM AND ENERGY IN NON-CIRCULAR DUCTS.
- (b) Laboratory project.
 - (c) Prof. W. D. Baines, University of Toronto, Toronto 5, Canada.
 - (d) Experimental, research for master's theses.
 - (e) The role of secondary currents in the diffusion of heat from the wall of a square duct is being studied. Comparisons are being made with the turbulent heat transfer rates.
 - (g) Correlations have been made between temperature and velocity distributions and shear and heat transfer rates. A device to measure local heat transfer rates has been developed.
 - (h) "Temperature and Velocity Distributions and Heat Transfer for Turbulent Flow in a Vertical Square Duct" by C. C. Alexopoulos, M.A.Sc. thesis, Univ. of Toronto, 1964.
- (4888) HYDRAULIC TRANSIENTS IN AN AIR VENT - SURGE TANK ASSEMBLY.
- (b) Laboratory project.
 - (c) Prof. H. J. Leutheusser, University of Toronto, Toronto 5, Canada.
 - (d) Experimental, basic research for master's and doctoral theses.
 - (e) Using an existing small-scale replica of a schematic penstock-inlet, pressure conditions due to air entrainment under various modes of gate and valve closure have been investigated. The study is being continued with emphasis shifted toward exploration of shape and transmission of interfacial wave separating the two regimes of flow.
 - (g) Significant negative pressures have been measured immediately in front of the interfacial wave.
 - (h) "Transient Hydraulic Phenomena in a Water Supply Conduit" by R. G. Witherell, M.A.Sc. thesis, Univ. of Toronto, 1964.
- (4889) UNSTEADY LAMINAR FLOW IN SHORT, CLOSED CONDUITS.
- (b) Laboratory project.
 - (c) Prof. H. J. Leutheusser, University of Toronto, Toronto 5, Canada.
 - (d) Experimental and analytical, basic research for master's thesis.
 - (e) Various cases of unsteady (oscillating) laminar flow as encountered in typical viscous damping devices are being investigated.
- (4890) CHARACTERISTICS OF FLOW OF FLUID-SEDIMENT MIXTURES.
- (b) Laboratory project.
 - (c) Prof. H. J. Leutheusser, University of Toronto, Toronto 5, Canada.

- (d) Experimental, basic research.
(e) Evaluation has been achieved of mean flow parameters such as friction coefficients, static pressures, velocities and wall shear stresses in a two-dimensional closed conduit.
- (5256) OPTIMUM HEIGHTS OF CHIMNEYS.
- (b) The Municipality of Metropolitan Toronto, Department of Works.
(c) Prof. G. R. Lord, University of Toronto, Toronto 5, Canada.
(d) Experimental, applied research for design information.
(e) Models of various configurations of block-type buildings, equipped with smoke stacks of variable height are being investigated in a low-speed wind tunnel at a ratio of gas emission speed to wind velocity equal to unity. Objective of study is to derive rules for the proper height of chimneys resulting in reduced aerodynamic downwash of the stack gases.
(g) Results available indicate significant effects of both windward face and plan of building on minimum stack heights required.
(h) "On the Minimum Height of Roof-Mounted Chimneys", by G. R. Lord, W. D. Baines, and H. J. Leutheusser, Univ. of Toronto, Mechanical Engineering Technical Publication Series, TP 6409, 1964.
- (5622) FLOW THROUGH AN OPEN-CHANNEL CONSTRICTION.
- (b) Laboratory project.
(c) Prof. G. R. Lord, Univ. of Toronto, Toronto 5, Canada.
(d) Theoretical.
(e) Analytical description of two-dimensional potential free-surface flow over a bottom hump.
- (5623) FLOW IN POROUS MEDIA.
- (b) Laboratory project.
(c) Prof. L. E. Jones, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and analytical; applied research for master's thesis.
(e) As an approach to fundamental investigations of fluid flow in porous media, a two-dimensional wavy channel will be used to study viscous flow. The initial study involves a "one-period" channel.
(g) Potential-flow computations are being undertaken on IBM 7094 computer.
- (5624) OPEN-CHANNEL PROFILE ANALYSIS.
- (b) Laboratory project.
(c) Prof. L. E. Jones, Univ. of Toronto, Toronto 5, Canada.
(d) Analytical, basic research.
(e) Fundamental computational projects are being reviewed and investigated by computer analysis.
(g) Unusual critical-slope characteristics have been discovered. A two-way extrapolation procedure shows promise in providing zero step-size results for numerically-integrated surface profiles.
(h) "Generalized Critical Slope for Trapezoidal Channels," by L. E. Jones and B. N. Tripathy. Scheduled for A.S.C.E. Hydraulic Division Proceedings, January 1965.
- (5625) PARTICLE TRAJECTORIES NEAR BLUFF BODIES.
- (b) Laboratory project.
(c) Prof. W. D. Baines, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental; applied research for master's thesis.
(e) Motion of particles falling through horizontal flow past a vertical flat plate has been studied by photographing trajectories.
(f) Completed.
(g) Dimensionless parameters have been combined as result of experiments to give simple presentation.
(h) "Falling Particle Trajectories in Flow Fields about Flat Plates", by R. J. E. Kerekes, M.A.Sc thesis, Univ. of Toronto, 1964.
- (5626) FLOW IN A WEDGE WITH POROUS WALLS.
- (b) Laboratory project.
(c) Prof. W. D. Baines, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) The flow of a fluid with a narrow wedge (less than 10 degrees included angle) is being investigated for walls made of screen. Pressure gradients and velocity distributions are being studied.
(g) Peculiar characteristics have been found for flow approaching a screen at a small angle. Pressure drop is much greater than that predicted by simple theory.
- (5627) BUILDING AERODYNAMICS.
- (b) Division of Building Research, National Research Council of Canada.
(c) Prof. H. J. Leutheusser, Univ. of Toronto, Toronto 5, Ontario.
(d) Experimental; applied research for design information.
(e) Determination of pressure distributions for block-type and cylindrical buildings in a constant-velocity wind field. Critical analysis of model testing techniques as employed in building aerodynamics.
(g) Parapets tend to make roof-pressure distributions more uniform, without, however, changing the average lift coefficients for roofs. Pressure distributions on bluff bodies have been found to change with Reynolds number in the range of operating conditions normally used in low-speed wind tunnels. Tests in constant-velocity wind fields require sufficiently long model ground plates in order to prevent entrainment of fluid into the building wake.
(h) "The Effects of Wall Parapets on the Roof Pressure- Coefficients of Block-Type and Cylindrical Structures", by H. J. Leutheusser, Univ. of Toronto, Mechanical Engineering Technical Publication Series, TP 6404, 1964.
"Parapets Improve Roof Wind Loading", by H. J. Leutheusser, Consulting Engineer, Volume 23, No. 6, December 1964.
- (5628) WATER-FLOW-INDUCED AIR CURRENTS.
- (b) Laboratory project.
(c) Prof. H. J. Leutheusser, Univ. of Toronto, Toronto 5, Ontario.
(d) Experimental, basic research for master's thesis.
(e) Using a covered 50-foot tilting flume, air motion as induced by uniform open channel flow is being studied.
- (5629) DYNAMICS OF A TURBULENT LINE VORTEX PAIR.
- (b) Laboratory project.
(c) Prof. J. F. Keffer, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) Counter-rotating turbulent line vortices are convected by a free stream. The characteristics of the turbulence, entrainment, velocity profiles and vortex interaction will be determined by conventional hot-wire anemometer equipment and visual techniques.
- (5630) MOTION OF BODIES IN STRATIFIED FLUIDS.
- (b) Laboratory project.
(c) Prof. J. F. Keffer, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) The initial wake formation, asymptotic turbulent wake, and, for unsteady motions the added mass, will be examined for

various shaped bodies. A heated wind tunnel is to be used to obtain stratification.

(5631) INVESTIGATION OF PERIODICITY IN TURBULENT WAKES.

- (b) Laboratory project.
- (c) Prof. J. F. Keffer, Univ. of Toronto, Toronto 5, Canada.
- (d) Experimental and theoretical; basic research.
- (e) With hot-wire anemometer and flow visualization techniques, characteristics of a turbulent wake are examined. The wake has been strained laterally to amplify turbulent motions.
- (g) Results indicate that the large eddy motions have a definite periodicity, not directly related to Karman frequency. Indications are that large motions are initiated by interaction of Karman street with lateral periodic motions. A more detailed investigation of conditions during the breakdown into turbulence is to be made.
- (h) "The Uniform Distortion of a Turbulent Wake" by J. F. Keffer, Journ. of Fluid Mechanics (in press).

(5632) DIFFUSION OF MASS IN NON-CIRCULAR DUCTS.

- (b) Laboratory project.
- (c) Dr. E. Brundrett, Univ. of Toronto, Toronto 5, Canada.
- (d) Experimental; applied research for master's thesis.
- (e) The role of secondary currents in the diffusion of tracer gases such as CO_2 is being investigated in a vertical square duct.
- (g) The results to date are supported by previous work which defined the magnitude of the secondary currents.

(5633) INNER- AND OUTER- LAW CORRELATIONS OF TEMPERATURE AND VELOCITY IN TWO- AND THREE-DIMENSIONAL BOUNDARY LAYERS.

- (b) Laboratory project.
- (c) Dr. E. Brundrett, Univ. of Toronto, Toronto 5, Canada.
- (d) Experimental; applied research for master's thesis.
- (e) Inner- and outer- law correlations have been applied to demonstrate the validity of an analogy probe to heat transfer similar to the Preston tube for wall shear stress. Overall

heat transfer results have also been obtained from flat plate and non-circular ducts.

- (f) Completed.
- (g) Continued investigation of the analogy probe is anticipated.
- (h) Results to be published in the April edition of AGARDograph, with the results to be presented at the AGARD Naples meeting in May 1965.

UNIVERSITY OF ALBERTA (EDMONTON), Dept. of Civil Engineering.

(5654) ALBERTAN CO-OPERATIVE STUDIES OF RIVER REGIME.

- (b) University, with NRC grant.
- (c) Dr. T. Blench, Dept. of Civil Engrg., Univ. of Alberta, Edmonton.
- (d) Laboratory study, Master's thesis.
- (e) Attempt to reproduce and extend work reported in literature on relatively steady density current flow through a reservoir. Continuing.
- (g) Data were obtained for various ratios of depth of current flow to depth of overlay in a range that permitted linking the ranges reported by Ippen & Harleman and by Levy in Proc. IAHR, 1959. The effect of the ratio was obtained roughly. Salt solution and silt suspension were used separately to produce the currents in a 120 ft. long flume.
- (h) "A Study of the Thickness of Density Currents in Reservoirs". Mangal Das Chawla, M.Sc. Thesis, University of Alberta, 1964.

(5655) ALBERTAN CO-OPERATIVE STUDIES OF RIVER REGIME.

- (b) University, with NRC grant.
- (c) Dr. T. Blench, Dept. of Civil Engrg., Univ. of Alberta, Edmonton.
- (d) Laboratory study, Master's thesis.
- (e) Study nature of advance of aggradation upstream of a new reservoir, using field information and a simple model.
- (f) Continuing.
- (g) Nature of advance differs from expectation. The extent of the advance is as expected. A new method of studying the mechanism is being devised.
- (h) "Exhaussement du lit a l'amont d'un reservoir". B. Harvey. M.Sc. Thesis, Univ. of Alberta, 1964.

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